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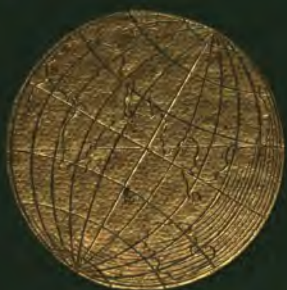

OR

THE GLOBE WE INHABIT.

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BY

R. MACKLEY BROWNE, F.G.S.,

AUTHOR OF "ASTRONOMICAL GEOLOGY."

"The works of the LORD are great, sought out of all them that have pleasure therein."—*Ps.* cxi. 2.

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PREFACE.

It was after no mere hasty consideration of the matters he discussed in the Treatise which he published upwards of two years ago, that the Author of this Volume then ventured into print. At various intervals in the course of many years he had used the opportunities afforded him in his rambles at home and abroad to make himself practically acquainted with the most conspicuous evidences which the rocks furnish respecting their own origin and history. The more closely he examined those evidences with the help of the written works of our leading geologists, the more plainly and convincingly did they seem to indicate that the existing condition of the earth's "crust" resulted from a most gradually developed and an ever-progressive course of events.

That the upper portion of the dry land consists for the most part of marine sedimentary deposits is necessarily admitted on all hands to be a proof that existing

continents and islands have been, during some former time or times, submerged beneath the water which constitutes the oceans of the world. There seems to be no doubt also, that, at the present day, a deepening of the sea is taking place in the neighbourhood of some coasts, while elsewhere the dry land is found to be rising higher above the sea level.

The occurrence of such a change in the relative positions of the land and sea surfaces is naturally suggestive of the question, whether it is not an effect that arises from circumstances connected with the ocean itself, rather than from the distension and contraction of the solid earth. On the inquiry being prosecuted with especial reference to the actual condition of the aqueous rocks, and with the aid which is derivable from the explanations of astronomy respecting the motions of the globe and the mode in which the waters upon its surface are affected by the influence of gravitation, it appears to be demonstrable that the phenomenon in question is attributable to an astronomical origin.

Since the publication of his former book the Author has striven to test in various ways the accuracy of the conclusions he had formed. But, neither by the means

he has resorted to for that purpose, nor in the criticisms of his Treatise which appeared in various journals, has he been able to discover any substantial reason for believing that the theory he had the boldness to advance is incorrect.

In the following pages he has endeavoured to describe in a plain and practical manner some of the actual circumstances from which that theory is deduced, and he presumes to hope that the topics which are therein brought forward may be deemed sufficiently important to justify the consideration of geologists, and that they are so introduced as to be of some interest to the general reader.

Hampstead,
November 1867.

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CAUSE AND EFFECT;

OR,

THE GLOBE WE INHABIT.

FROM THE CLOUDS TO THE OCEAN.

PART I.

VAPOUR, RAIN, AND RIVERS.

The effects of heat and cold upon aqueous vapour—Clouds and rain—The sensitiveness of water to the influence of gravitation—The variable characteristics of streams and currents—Rivers.

THE various circumstances connected with the existence of rivers, the different kinds of scenery through which they find their way, their fertilizing influence, and their utility to mankind, are matters of very general interest. Often, in prose and in verse, the progress of rivers has been traced, from their sources far up among the mountains where their nestling homes are romantically supposed to be, down to the vast ocean wherein they become lost, and where their individuality and identity entirely disappear. And when it is considered how greatly they contribute to the picturesqueness of the landscape, with how many human interests they are associated, and

how important are the functions they fulfil in the economy of the earth, it does not appear surprising that their history should be thus usually regarded with pleasure.

That phraseology descriptive both of river and sea is readily and pleasurably appreciated is shown by the common adoption of such expressions as the "stream of time," the "ocean of eternity," the "current of events," and the "tide in the affairs of men;" and even our religious sentiments and affections are often stimulated and refreshed by the allegorical use of a similar class of terms, of which "the pure river of the water of life," "a well of water springing up into everlasting life," and "living water," are instances frequently occurring in the Bible to denote ideas associated with the spiritual interests of mankind.

Without tarrying, however, to reflect upon the moral and sentimental ideas of which such phrases are suggestive, it is proposed to consider on the present occasion some of the influences that affect and regulate the element which not only forms the rivers, but occupies so important a place and performs so grand a part in the vast operations that are ever in progress on our globe.

Water may be described as consisting of infinitesimal particles or globules, which have so strong an affinity for each other that the instant any two or a few of them come into mutual contact they merge completely together, and form a larger globule or "drop." The readiness with which the particles become united may be witnessed in Alpine districts and other elevated places, where the aqueous vapour of the clouds becomes first condensed

into rain-drops so minute as to be scarcely larger than the vaporous particles themselves. In the earlier part of their descent the smaller rain-drops combine into larger ones, and thus the contents of the clouds are ultimately resolved into globules or drops of a somewhat equal weight and magnitude, which reach the earth apart from each other in a nearly equally distributed shower of more or less copiousness. The influences, however, which cause particle to unite with particle and drop with drop cease to be exercised as soon as any further amalgamation of the rain would produce injurious effects upon the earth. It is plain that, if the combination of the rain-drops were not thus arrested at the proper moment, the most devastating results would ensue.

Almost every one is more or less acquainted with the manner in which aqueous vapour is affected by heat and cold. The quick absorption by the atmosphere in dry weather, and the rapid disappearance, of the little clouds of steam blown off from locomotives, is a familiar and homely illustration, showing how soon the minute particles of which the vaporized water consists become dispersed in the air. Their weight is not sufficient to permit them to descend towards the earth; and, instead of condensing and coalescing into drops, they are diffused into space. This influence of heat may be seen by the traveller in mountain districts, where fields and patches of snow are exposed to the full glare of the morning sun. From different spots in those situations, and especially from snow-covered peaks, where such exist, the white vapour may be seen to arise in little volumes of various

forms. The vapour soon accumulates into small clouds, which sometimes remain suspended over the place where they have been formed, and go on increasing in size during several hours if the atmosphere happens to be quiescent. Often, however, it is slowly carried off by the gentle motion of the air, in the form of curled-up little cloudlets, or as attenuated streamers of considerable length. Sometimes a cloud may be seen to become formed by the onset of a cold air-current against the side of a projecting rock-mass, which, owing to its having been exposed to the sun's rays, radiates a considerable amount of heat. The previously invisible vapour contained in the atmosphere seems, under these circumstances, to become condensed by the mingling of the cold air-current with the air thus heated by radiation from the face of the rock.

The condensation of the aqueous vapour of the clouds, as seen in the production of rain-showers, is a beautiful instance of the absolute perfection with which the innumerable and apparently complicated operations of nature are adapted to each other, and produce their designed results. On the one hand there is effected, by means of heat, the vaporization of water into particles so infinitesimally minute that the power of the earth's gravitation is insufficient to attract them; and on the other, the cooling of the atmosphere to an extent inadequate to produce refrigeration, but sufficient to ensure a limited amalgamation of particles, causes the clouds to become resolved into rain-drops, which thus, by the influence of gravitation, descend to the earth in refreshing showers.

The production of rain by those very means whereby

the oceans of the world are maintained and regulated, is a marvellous illustration of the fact, that different effects are made to result from the operation of the same natural law. With what wonderful exactness and specialty of adaptation to designed ends must the various influences be exercised which regulate the operation of the great law manifested in gravitation, so that while it causes the vaporous particles to descend in rain-drops to the earth, they are prevented from coalescing further than is needful for the production of a shower, and are then gathered together in rills, streamlets, and rivers,—forms of another character, but still most sensitive to the influences of the same law,—and finally combined into vast aggregations of sea and ocean.

Our admiration of the beneficent wisdom with which this department of nature has been ordained and is regulated cannot but be enhanced when we come to analyze and trace more fully the operations under review.

It is usually supposed that the water in river, lake, and sea, is continually undergoing a process of evaporation by means of the sun's heat, and that it comes to be formed into clouds which return to the earth in the showers which have been described. It cannot be questioned that such a process is in constant operation on a very extensive scale, but it can only be a very small portion of the earth's watery envelope that becomes thus resolved into a more elemental condition. The oceans of the world are in fact as abiding a part of our planet as is the dry land itself; and they seem to be properly regardable, not as being ever in a state of dissipation

and renewal, but as an original and a permanent creation. That their saline property was imparted to them at or soon after their formation seems to be shown by the fact, that it is a characteristic which is not diminished by evaporation, but would be enhanced by it but for the replenishment of water which is condensed from the evaporated vapour produced from them; and from that circumstance alone it may be inferred that they were once and for good established, and that the rain formed by the process of evaporation and condensation is only a comparatively infinitesimal fraction of their entire volume, and is but an incident in the more fully developed physical condition of our planet.

It often happens in warm summer weather, and especially in more southern latitudes, that the atmosphere is so clear that not a cloud or particle of vapour is to be seen; but from the fact that a reduction of temperature is generally followed by or causes cloud and rain, it is evident that moisture exists in the atmosphere even at such times; and the conclusion we are justified in forming is, that the vapour is then so completely dissipated in space by means of heat, as to offer no visible indication of its presence, and that it exists in an elementary form through a considerable distance round our globe, even if it be not dispersed in the shape of almost infinitely minute atoms or particles throughout the vast regions of space.

The atmosphere thus appears to be capable of absorbing moisture in a variable degree,—sometimes holding it in a greatly dissipated state so that it is invisible, at

others retaining it in a condition of general or pervading mistiness, and at others, again, suspending it under various aspects in cloudy collections of different sorts. In other words, it may be said that moisture exists in a more or less condensed form according to the influences to which it is exposed; the two extremes of its condition being vapour dissipated throughout a great region of space around the globe, on the one hand, and, short of a state of congelation, the water of which river, lake, and ocean, consist, on the other.

Between these two extremes it presents itself to our notice in a very great variety of forms. It is seen in the white fleecy vapour which is sometimes suspended in attenuated patches at a great elevation above our heads at summer noontide, as well as in the dense livid thunder-cloud which seems to threaten a bodily descent to the earth in one heavy and destructive mass; it is manifested in the refreshing dew which affords a partial compensation for the absence of rain-showers in times of drought, as well as in the deluging down-pour of the summer storm; and it exists, not only as the early autumn mist beneath which the landscape oft-times lies concealed till high sunrise, and as the dense bewildering fog of the vast Atlantic, but also as the trickling rill and the roaring cataract of mountain solitudes, as the ever down-flowing river, and as the restless, globe-encircling ocean.

The great sensitiveness of water to the influence of gravitation may be explained as arising from the circumstance of each particle being independently affected by it. And when any body of water exists in the form

of a stream or current, it may be said of each of its constituent particles, not only that it has, in virtue of gravitation, an independent momentum of its own, but also that it is affected by many other motive influences. Each particle, for instance, is subject to compression by the mass of water surrounding it, to depression by the weight of water above it, and to resistance, in that it is borne up and prevented from immediately finding its way to the underlying surface, if there be any depth of water beneath it. Moreover, while each particle receives a down-stream impulse from the motion of the water forming the up-side portion of the current, it is also attracted or drawn in the same direction by the influence of the down-side portion of the stream.

If such are the complicated circumstances to which the constituent particles of any body of moving water are exposed, it does not seem difficult to account for that extreme sensitiveness to the influence of gravitation which is the characteristic of that element. For the purpose of tracing the causes to which that sensitiveness is due, it may be convenient to regard a stream or current as consisting of small indefinite aggregations of globules or drops, which unite and merge together as completely and with as much eagerness and facility as do the infinitesimal particles themselves, all of them also having an independent momentum, and being, at the same time, most susceptible to the numerous motive influences by which they are surrounded. Water in motion being thus constituted, it must happen that the velocity and direction of any one part of a stream is dependent

very much upon the volume of the neighbouring parts, as well as upon their direction and velocity. While, therefore, the motion of such a collection of water, when flowing in one general direction, is the one general effect of gravitation, the different parts of the stream are affected by various circumstances, and are ever undergoing changes or variations in their condition. Thus, neighbouring parts of a stream differ from each other in regard to the velocity as well as the direction of their motions; the variety in the circumstances by which they are directly influenced preventing any two or more of such parts, taken either horizontally or vertically, from having either parallel motions or equal velocities.

The conclusion thus theoretically deducible from a consideration of the circumstances under which the motion of streams and currents is maintained, is the same as that which has been ascertained by actual experiment. Any section of a stream being selected, it has been found that its velocity at the middle of the surface is greater than that at the sides, and that the velocity of its upper parts or strata is greater than that of its lower ones. It requires, indeed, but a very cursory glance at any stream, to see that the velocity and direction of its motion in its different parts do thus vary to a considerable extent, and not only that they are very readily affected by the most trivial impediments, but that they are subject to continual alteration.

It would appear, therefore, that the condition of any stream or current depends upon a great variety of circumstances. In the case of a river, while the subjection

of every particle, and aggregation of the particles, of the water of which it consists, to the influence of gravitation, is the primary cause of the great difference in the condition of its various parts, its general condition is, in fact, regulated and determined by a multitude of other circumstances, such as the form, width, and depth of its channel, the bends or turns in its course, the inclination of its bed or the degree of its departure from horizontality, and the quantity or volume of water of which it is composed.

The features of the different parts of every river of any magnitude vary greatly in character, whether it be one that rises in mountainous districts, as in the case of some of the beautiful rivers of Scotland, or one whose course is less varied as regards the elevation of its different portions, as in the case of the picturesque rivers of England. Thus, it often happens with rivers rising in mountain districts, that the first part of their course is through narrow, rocky, and precipitous channels, and they are usually characterized in such localities by falls of different heights, and by a motion of a great velocity; but when they reach open and more level districts they widen out and flow more slowly and uniformly; while those originating in regions which are not mountainous, as the Thames and other English rivers, are more uniform in their course, yet even they are marked with considerable variety. In all cases, however, the velocity of the stream in any part depends upon the inclination of its bed, that is to say, the degree in which it departs from horizontality; and wherever the bed or

channel is perfectly horizontal, there must exist a tendency in the water to accumulate in that place.

Hence the origin of lakes is due, in a great measure, to the horizontality of the bed of the stream in localities which form resting-places for the ever on-flowing waters. In the course of nearly all rivers of great magnitude, especially in mountainous regions, where the valleys have more or less contracted entrances and exits, chains of lakes occur in the more level situations where the water has accumulated until its surface has attained the height of the barrier by which its onflow was arrested; the size of the lake being chiefly dependent upon the facilities for the discharge of its waters, as compared with the quantity or volume of the in-flowing current.

Every river flowing into the sea is also influenced to a considerable distance upwards from its entrance by the body of sea water which occupies the lower part of its channel, it being by means of the tides of the ocean that it experiences, in any part of its course, the effects of an ebb and a flow of its waters. Thus, in the case of the Thames, the salt water forces its way many miles up the river, and it gradually becomes more and more mingled with the down-flowing fresh-water current, until no degree of brackishness remains. Throughout a distance, however, of twenty or twenty-five miles above the part where the stream entirely ceases to be impregnated with the salt water, the tidal alternations regularly take place, the flow or rising tide occurring in consequence of the fresh water in that part of the river being borne back by the influx of the salt water into its lowermost

channels, and the ebb or falling tide being produced by the removal of that barrier. It is, in fact, only where the natural condition of the river is interfered with by the artificial means of locks that the tidal effects cease to be manifested; and there cannot be a doubt, that if those impediments did not exist, the rise and fall of the sea water, to the extent of from eighteen to twenty-two or twenty-five feet in the lower part of the river channel, would exercise a very considerable influence upon the general condition of the stream throughout many miles of its course above the present tidal range.

Thus, it appears, that between the time of the aqueous vapour being formed by means of evaporation, and that of its union with the ocean, it is made to assume a variety of conditions, in consequence of its being acted upon in different ways by gravitation and other influences. Moisture is raised into the atmosphere and collected into clouds of more or less density. It remains suspended in the air at a greater or less elevation during periods of various lengths. By an imperceptible coalition of its particles it takes the form of dew, or it hovers over the earth's surface as a mist that is either transparent or more or less dense and impenetrable; it descends in gentle or copious showers, and is gathered into streamlets and rivers of various dimensions and velocities; it takes the form of the graceful cascade or roaring cataract, oft-times tarrying on its long journey to the sea, as the mountain tarn or expanded lake; and it exists in the condition of a vast oceanic aggregate, in which its agency in the physical economy of our globe is exercised with

enormous potency, and on a scale of immensity. Moreover, it is a necessary aliment of animal life, and while it is essential to the development and growth of vegetation on which that life depends, it subserves a great multitude of other beneficent ends. And in every phase of its existence it manifests the omnipotence which first evoked, and which ever continues to control and regulate it, as well as the consummate Wisdom and Goodness with which it, and the effects resulting from its instrumentality, have been designed.

The mode in which the ocean appears to be affected by the power of gravitation remains for consideration in a separate chapter.

FROM THE CLOUDS TO THE OCEAN.

Part II.

OCEAN TIDES AND CURRENTS.

Ocean currents are primarily due to gravitation—From astronomical explanations concerning the tides it is deducible how ocean currents are produced—By the globe's diurnal rotation the unchanged degree of terrestrial gravitation at any one place upon the earth's surface, is being continually brought into contest with a different degree of solar and lunar gravitation—The same course of operations is of daily recurrence, hence established effects ensue—One of such effects is manifested in the tidal alternations, and another in the ocean currents—Concluding observations.

Of ocean currents it can hardly be said that they are attributable to any other cause than that of gravitation, nor is it to be supposed that their *general* condition is much or at all affected by the outline or contour of the vast areas of dry land which rise above the sea, excepting where the water exists as a strait or occupies a narrow channel. The origin of such currents seems to be traceable to operations which are effected upon a much grander scale, and are of a more permanent character than are those to which rivers and mere secondary currents owe their existence. Of the Gulf-stream, for instance, which appears to flow continuously from the central part of the American continent to the northern shores of Europe, a distance of about one-fourth part of the globe's circum-

ference, it is difficult to imagine otherwise than that it is produced by some great and general cause that is very different in operation from any upon which the existence of a river or secondary sea-current is dependent. And when it is considered how the influence of the sun and moon is exercised upon the ocean in connexion with that of the earth itself, it does not seem difficult to understand that different portions of the vast collection of water with which the earth is encircled should have imparted to them a motion which gives them the character of permanent currents.

Concerning this part of the subject very reasonable conclusions are deducible from the explanations given to us by astronomers of the causes whereby the daily tides are produced.

Everybody knows that the greatest part of the daily tidal alternations is said to be occasioned by the influence exercised by the moon upon the ocean, and that the influence of the sun also contributes to the same effects, though in a smaller degree. In fact, the gravitation of the earth which holds the water to the globe is in some measure overcome by the gravitation of the sun and moon. Over whatever part of the ocean those luminaries happen to be vertical, or most nearly vertical, there is their influence upon the water exercised in the greatest measure; and there, and upon the part of the ocean diametrically opposite to that place, is the water drawn or raised up to the greatest extent.

The sun is of course always in the ecliptic, and the moon is always within about 5° of the same plane; it is, therefore,

always upon parts of the ocean which are nearest to the plane of the ecilptic that the greatest amount of solar and lunar influence is exercised upon the ocean. Now, as the moon revolves round the earth but once in the month; as her revolution is performed nearly in the imaginary plane of the ecliptic, which may be regarded as holding an absolutely fixed position in the heavens; and as the earth revolves round the sun but once in the year, always having its centre in that plane, it follows that the effect called "high water" would not occur twice, and sometimes four times daily, as it does, if it were not for the rotation of the earth upon its axis.

According to the astronomical explanations of the tides, it appears not improper to regard the water upon the globe as an envelope nearly surrounding it, and as being permanently deepest in the parts of it over which the sun and moon are vertical, and in the parts diametrically opposite to them; that is to say, in certain parts in each hemisphere which are situate under the ecliptic, or most nearly thereunder; for of course it happens that that imaginary plane passes through part of the continents as well as the oceans of the world. As the influence of the sun and moon, as it is exercised upon the water, decreases in some ratio according to the increase of distance between the attracting power and the object affected by it, it follows, the earth being spherical, that the water thus encircling the globe diminishes in depth in all directions surrounding those deepest parts, and that the solid part of the globe revolves within it.

Although there may be no doubt that the principal part of the water constituting the oceans of the world is carried round on the surface of the earth by means of the diurnal rotation, yet it is certainly to be inferred from the astronomical explanations of the tides, that a large proportion of it is retained or suspended by the solar and lunar influence in a manner which gives to it the character of such an envelope as that which has been described. It is plain that this is an absolutely necessary inference, if it be true that the daily tides are produced by the influence of the sun and moon upon the water.

Now, if the water upon the globe may be properly regarded as one entire collection, which is permanently maintained in the same general condition, so that it possesses a greater depth in those parts over which the sun or moon happens to be most nearly vertical, and also in the parts which are diametrically opposite thereto, the depth being diminishingly graduated in all directions surrounding those deepest parts to a distance of 90° therefrom, that is, to the extent of one-quarter of the earth's circumference, then it must happen that the diurnal rotation of the globe, whose direction is parallel with the plane of the earth's equator, but oblique with reference to the ecliptic, is always carrying every sea-shore and channel either towards or from those deepest parts of the envelope, and so that it becomes either more deeply immersed in the water or raised further out of it, in consequence of its being carried in a direction in which an increasing or diminishing depth of water occurs, as

the case may be, and hence are produced the effects of an apparently ebbing or flowing tide.

That such is a proper conception of the mode in which the daily tides occur, appears to be incontrovertible. For the sake of simplifying the matter, let the tidal influence exercised by the moon be considered separately from that of the sun. If, in virtue of the influence of its gravitation, the moon raises a volume of water which is deepest at the part of the world over which she happens to be vertical, it is manifest that that volume of water (or wave, as it is usually, but erroneously, spoken of) cannot be said to travel round the earth once in the course of each revolution of the earth on its axis, for the moon, upon which it is dependent, revolves round the earth only once in a month. As regards the lunar part of the tides, therefore, there is no alternative but to conceive that it is in consequence of a sea coast being brought by the earth's diurnal rotation on its axis to a position which is nearest to that part of the ecliptic in which the moon happens to be situate, that the phenomenon of "high water" is manifest on that coast. It is plain also that the circumstances of the case admit of no other supposition than that the volume of water thus produced by the moon's influence has a depth which is graduated, in some ratio, according to the precise position of the luminary in the ecliptic, and therefore that the occurrence of a flowing tide on any coast arises from the coast being brought by the earth's diurnal rotation towards the part of the ecliptic in which the moon happens to be, and that an ebbing

tide occurs by reason of the coast being carried away from the same part of the ecliptic.

The solar part of the tides may be explained exactly in the same manner, excepting that the earth's change of situation relatively with the sun in the ecliptic, on which it depends, is much slower than is the moon's change of situation relatively with the earth. The occurrence of "spring tides" arises from the influence of the two luminaries being exercised either from the same part of the ecliptic, as when the moon is "in conjunction" with the sun, or from opposite parts, as when she is "in opposition" to it.

Thus it is obvious that the daily tidal alternations observable on sea coasts, and in sea channels such as the lower portions of rivers which discharge themselves directly into the sea, cannot be said to consist of an actual advance and recession of the water to and from such coasts and channels; but they really occur in the manner stated, namely, in consequence of the water surrounding the globe being permanently maintained by the solar and lunar influence or gravitation, in a condition of unequal though regularly graduated depth, and by reason of the coasts and channels of the sea being carried round by the earth's rotation on its axis, in a direction in which the water is deeper or shallower, as the case may be, according to the position of the sun and moon in the ecliptic.

Such then is a brief outline of the manner in which the tidal phenomena occur; and although it is not a full exposition of the subject, it may be sufficient to show that the gravitation of the sun and moon, as exercised upon

the waters of the ocean, is not equable in all parts of the world. It is exercised to the greatest extent at those parts over which the luminaries are vertical, and effects, like those it produces there, are produced at those parts of the world which are diametrically opposite to the parts first mentioned. And surrounding those parts of greatest depth, for a distance of 90° therefrom, or one-quarter of the globe's circumference, the depth of water is diminishingly graduated.

These effects are manifested (1st) in consequence of the force of the sun and moon's gravitation, as exercised upon the water, overcoming that of the earth itself; and (2nd) by reason of the amount or degree of that force, as exerted upon the water on any particular part of the globe, being dependent on the situation which that part of the globe holds relatively with the attracting luminaries.

The force of the earth's gravitation, though different at different parts of the globe's surface, of course remains unchanged at every one place. But the diurnal rotation of the earth is always causing every one place upon the globe's surface to alter its situation relatively with the sun and moon, that is to say, it brings the place into a situation where the amount or degree of the solar and lunar influence is different from that exercised in the situation the place previously occupied. Therefore, it must happen that the same amount of the earth's gravitation, at every place upon the earth's surface, comes every moment to be exercised in opposition to a different amount of solar and lunar gravitation; and hence the water, which is sensitive in the extremest degree to any alter-

ation in the amount of the force or attraction exercised upon it, is, by the earth's daily rotation on its axis, made subject to continually altering or modifying influences. The force of the earth's gravitation, as existing at any one place on the globe, is being continuously brought into contest with a larger or smaller degree of solar and lunar attractive power, and a motion is imparted to the water in consequence of its becoming instantaneously subservient to the strongest of the contending forces.

A motion, then, being imparted to every part of the waters of the ocean, by reason of a continuous change in the circumstances by which they are influenced, how comes it to pass that the water should anywhere acquire the condition of a regular stream, which ever flows on in the same general direction, (though subject to slight periodic changes,) as occurs in the cases of the gulf-stream, and the equatorial and other great oceanic currents?

The circumstance of the solar and lunar influence being exercised from situations which are always somewhere in or near the immovable plane of the ecliptic, seems to offer a *general* solution to the question. By reason of the earth's daily rotation on its axis, every part of the ocean is being continually brought into an altered situation relatively with the ecliptic. On any part attaining a position as nearly under the sun or moon as circumstances permit, it becomes subjected to the greatest amount of influence either luminary, or both together, can exert upon it; from that moment, however, until it has been carried to a distance of 90° from that position, the amount of the solar or lunar influence

is exerted upon it in a diminishing ratio; but as the power of the earth's gravitation at any one place always remains the same, the latter prevails more and more during that period. Hence the solar and lunar influence being relaxed to an increasing extent, the portion of the water acted upon by it falls or is drawn towards the earth's surface in virtue of the force exercised by the earth's gravitation, that is to say, its efforts are exerted towards bringing itself into a condition of equilibrium, and it thereby attains the regular motion of a stream or current. On the same part of the ocean, however, arriving in the position last named, an increasing amount of solar or lunar influence begins to be exercised upon it, and the water is drawn up towards the attracting power in an increasing ratio until its arrival at a position as nearly under it as it can reach, and by that means the regular motion of a stream or current is also imparted to the water.

Now, excepting the most slow and gradual alterations in the direction of the earth's motion which give rise to the phenomena of "nutation" and "precession"—alterations which need not be here discussed—the diurnal rotation of the earth on its axis is each day bringing successively every part of the globe's surface into the very same position relatively with the ecliptic that it occupied the day previously. In fact, every place upon the globe is, by means of the diurnal rotation, made to describe a circle which ever retains the same situation relatively with the ecliptic; and therefore, though the place is undergoing a continual change of position

in relation thereto throughout each revolution of the globe on its axis, the same course of change recurs every day. Hence, whatever alterations or variations in the condition of the ocean are produced by the diurnal rotation of the earth upon its axis, they are of perpetual recurrence in nearly the same order, and they are consequently manifested as established effects, as in the daily tidal alternations and in the different oceanic currents,—effects, however, that are subject to such variation of condition as results from the monthly revolution of the moon round the earth very nearly in the plane of the ecliptic, and from the earth's yearly journey in orbit—her centre being, of course, always in that plane.

It thus appears to be in virtue of that physical influence which is usually described as the law of gravitation, that the contents of the clouds become discharged upon the earth in refreshing showers, and then formed into rills and river streams which find their way down to the distant ocean, wherewith they become entirely merged and wherein they are for ever lost. Another effect of gravitation is the permanent retention upon our globe of the vast collections of water of which sea and ocean consist. And the same law or influence, in connexion with the rotation of the earth upon its axis, not only produces an apparent rise and fall, or flow and re-flow of the water, wherever a sea coast or channel presents an opportunity for observing and marking the tidal phenomena, but also gives to different parts of the ocean the characteristics of streams or currents.

In tracing the various effects presented to our notice in any department of physical nature, we cannot but observe how many results of different kinds are made to emanate from one elementary cause, nor can we fail to perceive how unmistakably, though unconsciously, the various operations reviewed proclaim the omnipotence, the perfection of the wisdom, and the beneficence of the designing and superintending power by which they have been called into activity and are regulated. We may happen to be upon a mountain and viewing an extensive landscape under all the advantages of a clear and quiet atmosphere and of cloudless sunshine, when a distant little cloud first becomes expanded and enlarged, and then acquires a motion which causes its dark shadow to glide mysteriously over some of the hills and valleys within ken. Presently it increases to more noticeable dimensions—the sunshine disappears, and the distant parts of the scene are obscured. Then we are conscious of a moistness in the air around us, and by imperceptible degrees we become enveloped in a dewy mist which, though at first hardly visible, soon manifests its presence by its effects upon our apparel. Hastening our steps downwards we find ourselves in a rain-shower, and numberless little rills soon appear on all sides as if suddenly called forth by some magic power. Descending further, we find the rain to be heavier and the streamlets to be larger and more numerous, and by the time we arrive in the valley we discover that a violent rain-storm is raging. The water is tearing in swift currents through innumerable little channels, and is pouring over the precipitous hill-sides in

graceful little cataracts; and that which we crossed on beginning our ascent as a winding rivulet, in the middle of the then nearly dry rocky bed of "the" river of the valley, has already swollen into the dimensions of a considerable stream, and is hastening on its long journey to the sea with an impetuous velocity.

It is not intended to be asserted that rain descends with more gentleness in elevated districts than it does in lower ones, for the reverse is often the case; but where hills or mountains exist it is usually upon them that the clouds are first "broken" in the manner stated, and that a shower commences. The traveller over mountain passes can speak of the violence with which the clouds sometimes discharge themselves when rainy weather fairly sets in, and of his experience leaving no wonderment in his mind that every rocky slope and precipice in such localities should be utterly bare of soil and vegetation, and that the water should be quickly collected into cataracts of all dimensions, and, after finding its way into some deep mountain chasm, descend with roaring sound and clouds of spray from one dark abyss to another, until as a river it reaches the more level portions of its journey.

From the clouds to the ocean, then, how many are the forms which the aqueous element assumes, and how manifold are its operations! Yet, if instead of its being but one of an infinite number of absolutely unconscious incidents in nature, as it so manifestly is, it were sentient, and in possession of an intelligent, self-regulating and self-guiding power, in the fullest and wisest degree, could it possibly display more prescience than is proclaimed by

its effects, or fulfil more designedly and beneficently the ends which are accomplished by its instrumentality? It may be said that within certain limits which appear to be strictly prescribed, the more violent the elements contend together in mountain heights which man does not inhabit, the greater is the beneficial effect produced, as for instance in the increased quantity of fertile soil brought down into cultivable districts; but it is needful for the safety of man, as well as for the profitable tillage and pasturage of habitable regions, that the clouds should there distribute their contents more gently and equably, though perhaps with a not less aggregate copiousness, and nature is regulated accordingly. Both those purposes, again, require that the water should find its way to the ocean, not in vast sheets sweeping at random over the intervening distance by the shortest route, but at first by numberless little feeders formed in the surface of the soil, and then through deeper and wider channels, and in volumes of increasing magnitude, which become subservient to the advantage and convenience of mankind in various ways. And when the condensed aqueous vapour has thus performed its useful mission in effecting the innumerable results to accomplish which it was called into activity, it rejoins the marvellous ocean, which is as absolutely controlled, and as perfectly regulated, as is the most infinitesimal atom that rises from its surface in virtue of the sun's heat.

FROM THE NORE TO THAMES HEAD.

Introductory—The sand-banks and marsh-lands of the lower part of the Thames, and their intersecting channels—The general conformation of the land on each side of the river, including ancient sea and river cliffs—Shoeburyness to London, and onwards to Richmond—Richmond to Kingston and back through the park—Staines to Windsor—Maidenhead to Great Marlow, and upwards to Reading—Reading to Pangbourne and upwards—Wallingford to Culham—Abingdon—Oxford—Witham—Lechlade—Cricklade and Thames Head—General review of the journey, and the course of geological events indicated by the various features noted.

To what causes do rivers owe their existence, and by what means did the dry land acquire the irregularity of surface from which the picturesqueness of landscape scenery chiefly arises? The solution of this question involves the consideration of matters of considerable interest; for, as hills, valleys, and plains, rivers and lakes, exist in all parts of the world, they can only be supposed to have originated in some of those general operations of nature to which the present established condition of the earth is referrible.

On the present occasion it is proposed to consider some of the features presented by the parts of the country traversed by the Thames, with reference to the causes to which the irregularity of contour characterising the route pursued by that river is due. And, in order to carry the proposal into effect, a journey will be undertaken

from the Nore, where the river merges into the sea, to its source far away among the Gloucestershire hills.

The great variety of scenery to be found in the districts through which the Thames flows arises chiefly, as nearly everybody well knows, from the circumstance that the country on either side of the river is formed of different kinds of elevations which, in some places, constitute the banks of the stream, and in others are situate at greater or less distances from them. For, although large areas of marsh and of flat and nearly level meadow lands occur at intervals along the entire course of the valleys through which the river wends its way, yet, in no part of its journey to the sea is there a place whence hills or hill-ranges are not visible.

Of course it is not here meant that the route followed by the Thames is distinguished in any very important degree by features that are peculiarly its own; for, while the character of landscape scenery generally is chiefly determined by geological circumstances, and different districts are therefore often found to be very dissimilar, yet, in many respects, every river has numerous counterparts, while, in regard to some leading characteristics, all rivers are alike. The Thames, like every principal river, constitutes the natural channel through which the surface drainage of a large region finds it way to the ocean, and therefore its route has been necessarily determined by the configuration of the several districts whose waters are collected into it.

One of the plainest and most incontestible facts that the globe has recorded of itself is, that during some long-

past age, the parts of its surface which now constitute the continents and islands of the world have been submerged beneath a considerable depth of water. Hence it forms an interesting matter of scientific inquiry to trace the wonderful operations of nature whereby former ocean-beds have been raised above the water-floods; and although the following remarks will chiefly have reference to the hills, valleys, meadows, marshes, banks, and other river characteristics which are to be met with more immediately along the route to be pursued, yet it will be found that very important geological results are deducible from the external contour or configuration of the localities which will be visited.

The sandbanks and marsh-lands of the lower part of the Thames, and their intersecting channels.—An accurate idea of the character of the districts upon either side of the estuary into which the river discharges itself, and in the middle of which is the Nore Light, is to be obtained by reference to the Admiralty Chart of that locality. Upon it are very clearly delineated the banks of mud and sand which have accumulated in different parts of the river exit, and also the areas of land lying just above and beyond the reach of the tides. The banks that are situate immediately off the opposite shores of Essex on the one hand and of Kent on the other, and that are left dry during a portion of each tide, are of considerable extent. On the Essex shore is the well known Maplin Sand; then travelling upwards, the Southend Mud Flat; and after passing the inlet called Leigh Channel, the "Marsh-end" and "Chapman" sands follow in succession. It is shown

by the chart, and indeed the fact is plainly observable by any one happening to be in the neighbourhood during the particular period of the tide, that portions of those banks, especially such of them as are composed of materials more tenacious than sand, are traversed by an intricate ramification of regular channels which have been indirectly formed by the instrumentality of the tides. These channels remain occupied by the water during some time after it disappears from the higher parts of the banks. It is, in fact, into them that the more elevated areas become drained when the tide has receded to a certain extent. As a still further recession ensues, the smaller of these channels, which are discharged into the larger, are gradually laid dry, and finally, some or all of the main arteries themselves become entirely drained for a time after the banks are left high and dry above the reach of the waves.

Thus, these banks are completely submerged at the time of flood-tide, after which the water upon them becomes gradually shallower, until it no longer abides upon their most elevated parts. For a time, however, after their emersion has so far progressed, they are inundated every few moments, as the waves advance and retire. Their further elevation slowly goes forward and their emerged areas become enlarged. The water lodged by the waves upon their just emerged portions and that with which their more elevated parts are still more or less saturated, is collected into streams, and thereby channels are formed through which they continue to be drained as long as they remain unsubmerged by the return of the tide.

It is easy to perceive how, under these circumstances, channels should become permanently established in such banks, particularly if they consist of tenacious materials, as do some of those that are situate between Shoeburyness and Thames Haven. The "Knock," is an outer portion of the bank lying immediately off Shoeburyness, and it is completely isolated by channels of that kind. The entrances of the shallow mud-bottomed creeks or havens that partly surround "Canvey Island," are traversed by such; and similar ones have been formed in the "Blyth Sand" bank, which lies immediately off the Kentish shore, and directly opposite to Canvey Island.

The manner in which these banks are thus traversed bears a most striking resemblance to that in which the marshes and permanent dry land bordering the river entrance are intersected. Yantlet Creek, which isolates the Isle of Grain on the Kentish side of the river, and the havens immediately to the east and to the west of Canvey Island upon the Essex shore, would form channels exactly similar in character to those which exist in the present tide-flooded banks, if the maximum tide-flow were but a small measure more than it actually is. In that case those islands, and the low portions of the land upon either side of the river entrance would form the tide-flooded banks of a much wider stream than the Thames of our day. If, on the other hand, the maximum tide-flow were reduced in a very small degree, then would the present tide-flooded banks, according to their relative altitudes, become transformed into marshes and channel-intersected dry land.

The configuration of extensive districts lying upon

either side of the river seems to confirm that analogy in a very remarkable manner, and to be conspicuously suggestive of the Thames having had a vastly greater area and depth than it now possesses. High lands of different altitudes exist along its general course, at a considerable distance from the shores of the present stream. On the Kentish side they may be traced in an irregular line from Allhallows and upwards by Gravesend. In Essex their route is less direct—passing from Southend to Bemfleet and roundwards to Tilbury. On both sides they encompass extensive marsh lands, which are more or less intersected by natural or artificial water channels. Those high lands would form the shores of a river of much greater magnitude than the Thames of our time, if the depth of the sea surrounding our coasts were considerably greater than it is.

But the areas lying between those lines of hills and the actual river banks are not uniformly flat and level; they are sufficiently irregular, in regard to superficial contour, to justify the suggestion that they too, during some former time, constituted tide-flooded banks, and became gradually to acquire the condition of permanent dry land.

And when the configuration of different localities lying within these several districts comes to be actually examined in detail, and compared with each other, the conviction forces itself upon the mind, that the various features which that configuration presents have been produced by means of an imperceptible and a most slow and gradual subsidence of the sea surrounding our coasts,

and absolutely and altogether without any physical disturbance or upheaval of the districts from which the water has subsided.

The general conformation of the land on each side of the Thames, including ancient sea and river cliffs.

Shoeburyness to London and onwards to Richmond.—It would be attended with tediousness to comment upon all the elevations which border the river, and bear evident tokens of their having been operated upon by a stream of much greater magnitude than that of the Thames of our own days. It will be sufficient to select a few of the more conspicuous instances.

The first that may be noticed is Thorpe Cliff, which is the nearly vertical section of an area that has not a great elevation, but whose surface is some twenty or thirty feet above the sea level. The cliff has been evidently formed by the action of a current. The materials constituting the hill of which it is a section belong to a modern geological formation, and in all probability they were deposited in the same manner as were those composing the sand-banks of the present time. Subsequently to their deposition in that way, the water overlying the site became gradually shallower; at length the higher portions of the bank, or of that which is now a low rounded hill that was formed by the accumulation of those materials, were left permanently dry, and then, through a most gradually progressive modification in the general condition

of the river (resulting from the gradual shallowing of the water, and from a consequent alteration in the contour of the bed and shores of the river channel) the current came to set against this elevated bank, portions of which were slowly removed, until in course of time a nearly vertical cliff was produced.

Proceeding towards Southend, a low and marshy area is passed, and then the land gradually rises in the direction of that town, and attains a considerable elevation in the locality upon which the terrace is now situate. In fact a cliff has been there formed, and apparently by exactly the same means as those to which the existence of Thorpe Cliff is due, namely by the action of a current, whereby a large portion of a hill has been removed, so as to leave exposed a more or less vertical section of the remaining part.

It will be noticed as the journey is proceeded with, that over and over again, throughout the whole course of the Thames, cliffs of different altitudes are to be met with at greater or less distances from the present river banks; and that while they show by their contour and general condition, that they have been produced by one continuous course of operations, yet the hilly elevations in which they have been formed are not all composed of the same kind of materials, and belong to geological formations of different eras. Thus, in the cases just alluded to, the hill wherein Thorpe Cliff has been formed is constituted of materials belonging to a modern geological group, while the more elevated land, a section of which is seen in the Southend Cliff, is included in a much more ancient formation.

A few miles up the river, on its Kentish side, is a small village called Cliffe, which has evidently derived its name from a chalk cliff near to the margin of which it is situate. Viewing this cliff from the road near its base, and considering it with reference to the flat area above which it rises, it seems impossible to avoid the conclusion that it originated by the very means which were instrumental in forming the cliffs already commented upon. It is nearly perpendicular, and in a part of its exposed section the layers of flint usual in the upper chalk are revealed. It is forty to fifty feet high, and is nearly parallel with the river, from which it is distant about three-quarters of a mile. The intervening area is nearly level, and is in fact marsh land though traversed by roads. Evidently the cliff was formed by the action of the river when it flowed bodily over the area now forming the marsh which lies between its present channel and the cliff. That larger stream wore away a portion of the higher land, whose surface was continuous with the surface of the present high chalk land in which the cliff has been formed. Ascending to the village and proceeding towards Higham, a low range of hills is seen to lie a few miles off, having a direction generally parallel with that of the river, the intermediate country being very gently undulating, or what may be regarded as approximately flat, with a gradual descent, however, towards the lower elevations that overlook the river.

The low area lying between the cliff and the river consists of a comparatively recent deposit, and it is certain, that even if the barrier which protects it from flood did

not exist, the river would not overflow it, though it might be thereby rendered too swampy for agriculture through the free admission of the tide into the various channels which intersect it. In that case its flatness and its lowness of level might prevent it from being drained into the river, yet it is beyond question, that the river would not so invade it as to reach to the base of the cliff.

Bearing in mind that the soil (consisting of chalk), which forms the part of the country from the village of Cliffe landward, is undoubtedly sedimentary, the course of events to which the superficial contour of the neighbourhood is due seems to be plainly indicated. The river now occupies a channel whose actual banks consist of a vertical section of the soil of the low area which extends up to the base of the chalk cliff. That chalk cliff is forty or fifty feet high, and must have been formed in consequence of a much larger and deeper stream than the present acting erosively upon an elevation of chalk sediment which had been deposited in a long previous era. Probably, the distant range of low hills mentioned, once formed a bank of a yet larger stream; and if the configuration of a region extending many miles around the neighbourhood under review were examined, indications of a similar character would, doubtless, be discernible upon a yet larger scale, showing a still more extensive prevalence of the aqueous element in yet remoter times.

The nearly level area just referred to as lying between the present river channel and the chalk cliff at the village of Cliffe, is a portion of a strip of land of greater or less breadth which extends from Allhallows to near Gravesend,

and is bounded by an elevated district whose surface is deeply undulating. This higher district is composed of chalk with a superincumbent deposit of friable or sandy soil, which contains, in some localities, an intermixture of round black flint pebbles. Sections of this chalky region may be seen near Gravesend, Northfleet, and other places on the Kentish side of the river, while on the Essex side, as at Tilbury, there are low elongated hills having a lengthwise direction parallel with the general direction of the river. The constituent soil of these hills seems to be nearly of the same description as that which reposes upon the chalk on the Kentish side, and there cannot be a doubt that the similar deposits which lie on both sides of the river accumulated during the same period.

Passing again to the Essex shore, let the contour of the land bordering the river between Grays and Purfleet be noted, reversing, however, the order of the route in this part of the journey.

At Purfleet a bend in the river occurs, the cause of which may be readily deciphered, even by a cursory examination of the locality. Proceeding from London by the Tilbury railway, it may be seen that as the line approaches Purfleet from the comparatively flat land it had previously traversed, the country becomes more hilly. In fact a cutting was necessary, in order that a proper level might be obtained for the line. It is shown by the perpendicular sides of this cutting, that it first passes through a gravelly soil having a large intermixture of chalky particles ; then the line passes decidedly through chalk, and afterwards enters an extensive excavation which has been

made in olden times in obtaining the chalk for lime-making purposes. These ancient chalk pits are crossed by the railway just before the Purfleet station is reached. It is plain that over the area of chalk which has been removed there existed a considerable depth of sand, for there has been left standing in the midst of the excavations, a huge isolated mass of chalk, having its original superincumbent accumulation of well-compacted sand still remaining upon it. The sand and the chalk together present a vertical face of considerable height. Taking the high road towards Grays, other deserted chalk pits are visible, and there also the chalk is seen to be surmounted by sand. Beacon Hill lies upon the left of the road and forms part of the general elevation in which the chalk pits have been excavated. It is manifest that this general elevation consists of an extensive substructure of chalk with a crowning accumulation of sand, and it presents characteristics exactly similar to those existing at Greenhithe, Erith, and other places on the Kentish side of the river, where a considerable depth of sandy soil is seen to repose upon a nearly smooth and an approximately horizontal surface of the chalk.

Here then the river bends round the land, and forms a kind of elbow. The land is high, and consists of the chalk surmounted by sand, and it rises to a considerable elevation above the area which immediately borders the river. There is no mistaking the coincidence of this chalk hill with the bend of the river here occurring. In some far-off times, the stream, then of vastly larger dimensions than the Thames of to-day, was impelled

against this projecting high land. During its gradual subsidence the water, by its constant action, had previously removed a considerable portion of the elevation of which Beacon Hill is the remaining part, and subsequently, by a continued lessening of depth, it retreated within a narrower channel and left the present lower strip of land between the existing river bank and that former chalk cliff. In its long journey to the sea the river continually presents at intervals the same characteristics. It sets against a point of land first on one side of the channel and then on the other. The precise route of its zig-zag course is determined by various causes, but where the bank against which it is impelled consists of not easily yieldable material, there the current fails to sweep away the obstruction, and by which, on the contrary, it becomes itself influenced. And thus, between the banks of a river channel and the current which flows through it, is there at various points a continual contest for the mastery. As, however, the stream becomes most gradually reduced in depth and volume its force becomes more feeble, and it at length resigns the contest and recedes from the points it previously attacked.

As we continue to journey along the road leading to Grays, Beacon Hill is seen to be the highest point of a slightly descending and somewhat undulating line of hill, which has a direction more or less parallel with that of the river. On the right of the road are the West Thurrock Marshes, but so much has artificial embankment, combined with an ever progressive but most gradual diminution in the depth of the water in the river, done

for them, that they have been converted into fertile land. The richness imparted to their soil by nature or by art is seen in their crops of tall, large-eared wheat, to which a yellow tinge has been given by the glowing mid-July sunshine in which they are now being viewed. In short, the outline of the land on either side of this part of the route presents characteristics of exactly the same kind as those existing in other districts through which the river travels. The soil of the marshes or flat land on the right of the road is seen in some places, where diggings to the extent of three or four feet have been made in it, to consist of material that was deposited at the bottom of a quiet part of a large stream. Where deeper excavations have been made in the hill-side upon the left of the road, there the upper part of the rock sections is seen to consist of gravel confusedly intermixed with chalk flints, and in a downward direction to become gradually merged into the underlying chalk. Along the road are steep banks now covered with a profusion of tall, free-growing mallow, interspersed with the scarlet poppy, the elegant light blue succory, and many other full summer-tide floral gaieties; for this portion of our journey is being made in the middle of July. It may be, that some of those banks were artificially formed in the hill-side when the high road was constructed, but others of them manifestly retain the contour imparted to them when they were actual river banks. Banks of a similar description are to be seen on the right hand side of the road at some places where the hill-side slopes into the level land. They have the appearance of never having been disturbed by the plough.

The chalk pits at Grays have been excavated to some depth into the central parts of the hill-range last referred to. The floor of the pits is even with the high road, from which, to their deepest parts, a cutting has been made through the intervening slope of the hill. Hence the sides of the pits in the central parts of the hill are of considerable height. Their vertical sections present appearances similar to those exhibited in other neighbouring places where the chalk is quarried, there being a deposit of sand or light friable soil some twenty or thirty feet thick, which reposes upon the chalk in a way indicating that the surface of the latter had been worn smooth by the action of a stream, and that subsequently, when the water in the locality had acquired a tranquil condition, the deposition of the sandy sediment took place.

The geological evidences presented to our notice, then, in this further short excursion are of the same character as those elsewhere exhibited, and they seem to prove conclusively that in some remote period, subsequent to the deposition of the chalk, the hills composed of that material came to be swept by a current, and that in course of time the water in some localities, which had exercised an abrading action, acquired a tranquil condition, when the accumulation of sandy sediment ensued. The depth of water diminished, and some hills and hill-ranges came to be again acted upon by the water in such a way that they were not scoured at the top, but outlying parts of them that offered impediments to a wide river-stream were gradually removed, so as to leave cliffs or vertical sections of the hills exposed to view after a still further

subsidence of the water had taken place. The condition of the rock sections, wherever they are exhibited, defies the supposition of volcanic or any other subterranean physical force having been in operation beneath their sites since the sedimentary accumulations of which the hills are formed took place.

A short trip on the other side of the river, from Greenwich towards Erith, being now entered upon, the contour of the land along that route is seen to present indications of the same kind with those to be met with in other parts of the river's course. They comprise elevations of various altitudes and of different degrees of steepness, and lower areas intervening between them and the river margin.

The National Observatory appears from the lower part of Greenwich Park to have been built upon a steep hill. On ascending to it, however, and examining the locality in which it is situate, it is to be seen that the spot it occupies is part of an elevated area of very great extent, including Blackheath and adjoining districts. Its site consists of a sort of steep and rounded promontory, which projects from that elevated area and is of such a character that if it were less precipitous and were taperingly extended to a greater distance into the lower district at its base, it would form a lateral spur or offshoot from the higher area. Near it are similar projections. Their form arises from the circumstance of there being depressions between them which are, in fact, deep bays or inlets. Although the land at the base of these promontories or projections is very low as compared with

their summits, yet it is not perfectly horizontal, but gradually slopes towards the river.

Like many another elevated area (as that, for instance, in which Richmond Park is situate), the high land of which Greenwich Park forms a portion is more or less undulating; and nearly all the way to Charlton it has a marginal outline which is marked by exactly such bays and inlets and rounded promontories as those that are to be met with along the edge of so many other elevated tracts of country.

Standing near the Observatory, upon the brow of the elevation upon which it has been erected, and looking towards the north, the flat area which constitutes the Isle of Dogs is seen to owe its isolated character to the winding of the river, which flows down in a direction a little to the east of south, and then bends round to the north. Judging from the contour of the locality whence the landscape is being surveyed, it seems impossible to conclude otherwise than that a vast stream once filled the valley of the Thames, and was of such a magnitude that its surface reached nearly to the summit of the Observatory hill. Its course at that remote period was almost that of the present river. In this part it flowed down from a little west of north. Its southern bank was formed of this elevated district, against which it set with some degree of violence, and whereby it was impelled in a nearly opposite direction. Its continual action gradually wore away portions of the bank, and by its eddyings and other unequable operations, bays and inlets of various kinds were formed.

But anterior to those times there was a period when the whole of this part of our island was submerged. It requires but a very cursory inspection of the soil of the district to enable us to perceive that such was the case. At Blackheath, for instance, there have been dug for various purposes, deep pits whose nearly vertical sides show the soil to be composed of sandy or friable materials containing black rounded pebbles in vast abundance. At Charlton, pits have been formed in obtaining the light sand which there reposes upon the chalk, and which contains strata wherein there is a profuse intermixture of the same kind of rounded black pebbles. In some of the elevated parts of Greenwich Park the steep slopes are bare of vegetation, and there, even at the surface, the soil may be seen to consist of material wherein those black flint pebbles abound. Journeying from Woolwich along the hilly land skirted by the marshes which border the river all the way to Erith, it may be observed that the elevated parts of the country consist of the same kind of soil. Thus the road from the railway station at Abbey Wood rises from the marshes and ascends to the extensive plateau which includes Bostall and Bexley Heaths; and, in order to render the ascent less difficult, the road has been cut through the embayed escarpment of the higher land which overlooks the marshes. Here also the soil of the elevated district may be seen to consist of sandy strata having a like profuse intermixture of the same sort of pebbles. In fact, they are traceable for a considerable distance, both along the hills bordering the river, and landward even as far as Bromley and Chislehurst.

It is stated by competent paleontologists that the fossils found in some of the deposits included in what are called the "Woolwich beds," belong to genera or species that inhabited brackish water. Hence it is to be inferred that the materials constituting the hilly region under consideration were accumulating when that region formed the bed of an estuary at a river exit, wherein fresh and salt water were commingled, or of a tidal river up whose channel a considerable volume of sea-water continually forced its way. The fossils found in the neighbourhood, then, certainly indicate that there existed in the vicinity of Woolwich a considerable depth of brackish water. Even in our own time a slight saline intermixture may be often detected in water taken from the river at that place.

It may be here observed, that the soil which reposes upon the chalk at Greenwich and Blackheath, and which extends over many miles of the surrounding country, is of such a character that the stratified portions of it could not possibly have retained their original condition had any volcanic or other subterranean physical force upraised the site of its deposition to its present elevation. Indeed, all the indications that have been pointed out show most positively that it is from a most slow and gradual subsidence of the water that the difference between the land and sea surfaces has been occasioned.

The conformation of the land on either side of the Thames, along the further part of its route which passes through London, is suggestive of only a few general remarks; for so greatly has it been modified and altered by

artificial embankments and structures of different kinds, that only the most conspicuous of its original characteristics are easily traceable. Like every other part of the river's course, it has here on each side, and at a greater or less distance from the actual channel, a range of elevated land in the form of numerous hills, through the depressions between which, lesser rivers once flowed. In some localities between this hill-range—or rather, series of elevations—and the river, there are nearly level strips of land, while in others there are extensive low-lying areas which once formed marshes. On the side of Kent and Surrey are the comparatively low and level districts of Rotherhithe, Bermondsey, Southwark, Lambeth, and Battersea—names suggestive of their ancient characteristics—extending to the bases of the hills and hill-ranges that have a considerable altitude, and which include Nunhead, Denmark Hill, Brixton, Clapham, and Wandsworth. On the Middlesex side, there is a continuous line of hill, as nearly every Londoner so well knows, extending from Tower Hill, by St. Paul's, to the valley or depression through which coursed the ancient Fleet river at the base of Ludgate Hill. Between this elevation and the Thames is the low narrow strip occupied by Upper and Lower Thames Street, and which is continued westward at the base of the sloping ground whereon Fleet Street and the Strand have been formed. The river's course upward is then round the low-lying districts of Westminster, Chelsea, and Fulham.

On arriving at Chiswick, we meet with a feature of a kind which has not presented itself in the earlier part of the route, consisting of elongated islands, which occupy

situations in the midst of the stream. They occur at intervals throughout the remainder of the journey from this point upwards; and as the river scenery here is not so picturesque as that to be presently met with, the remarks of which those islands are suggestive will be reserved.

Richmond to Kingston and back through the Park.—It is from Kew Bridge upwards that the Thames affords the greatest attractions to the rower or pedestrian, for down to that point it wends its way amid scenery of a much softer character than that which is to be met with in the lower part of its course, where it bears so busy and commercial an aspect, and where, by reason of its greater magnitude, landscape views are not so easily obtainable from its shores or surface.

Without lingering at any part of the river side between Kew and Richmond, but proceeding to the latter place by the towing-path (so agreeable at high water) which skirts the gardens of Kew, let Richmond form a new starting-point, and let a short journey be made to Kingston, by the side of the river, the Park being taken on the way back.

Entering upon the lower road leading from Richmond Bridge to Kingston, which has been formed along a portion of the hill that rises from near the margin of the river with more or less abruptness, we presently come to a turning on the right which conducts us immediately into a river-side meadow. We have hence a good opportunity of viewing a portion of the far-famed Richmond Hill. It rises with so much abruptness, at a distance of perhaps a quarter of a mile from the river margin, that even if it may not be properly termed a cliff, at least it is a steeply sloping bank

of a very irregular contour. Towards its base the meadow gradually rises. On the opposite side of the river the land also gently rises from the margin of the stream. And here, towards the Middlesex shore, is one of the elongated islets which so plainly indicate a lessening depth of water, and of which there are so many in different parts of the Thames above the point where the tidal influence begins to weaken. It being just now the time of full spring-tides, that islet is completely submerged, only the upper portions of the osiers and of the willow trees growing upon it being visible. In seeking for the causes to which the locality owes its present characteristics, it seems impossible to conclude otherwise than that they were of exactly the same nature as those which are in operation on a greatly reduced scale, by means of the diminished current of our own times. After the water which once flowed over the entire country had sufficiently subsided, the upper part of Richmond Hill became the bank of a stream of vastly larger proportions than those of the present river. The current set with some violence against the western side of the hill, and continuing to exercise its eroding power during the further gradual shallowing of the water, it ultimately became so much diminished in depth that it retreated altogether from the base of the hill, and at last was reduced to its present comparative insignificance.

The river flows at some distance from the line of hill on part of which Richmond is situate, but even now its course here, which is directly towards that town—that is, from west to east—is very nearly the same as it was in some far-off ages, when as a vastly larger and deeper stream

it set against the western side of the hill, and occupied the whole of the valley that is now so picturesque with verdant meadows, ancient trees, and ornamental villa grounds.

Continuing the journey and passing a fresh foliaged hedge-bank, which is gaily decked with scarlet poppy, bright yellow nipple-wort, lilac-colored mallow, elegant purple thistle, and numerous other early summer flowers, an extensive tract of land opens to view upon the left, and it is seen to be not quite flat, but formed of low rounded hills, similar to those which exist at intervals throughout the entire route of the Thames, some of them being scarcely distinguishable as hills, and others being elevations of a more conspicuous character. Passing the well-known Eel-pie Island, the river bends to the left, and then its bank, along which is the towing-path, gradually acquires an increased altitude, until it reaches to a height of fifteen or twenty feet above the high-water surface of the stream. Here, in fact, are several steps or river-banks of former times, and the channel of the present day has evidently been formed by the removal of a portion of what was once an extensive submerged mound or hill; for the soil, upon this left side of the river, is seen to consist of a gravelly shingle.

Teddington Lock being passed, there occurs another rounded and elongated hill, having a lengthwise direction nearly parallel with that of the river, and then the towing-path lies along a horizontal bank, twenty feet in width, on the left of which is a perpendicular cliff about twelve feet high. From the right-hand margin of the horizontal

bank there descends to the surface of the stream another little cliff which, in some places slopes downwards more or less irregularly, and in others, is nearly perpendicular. All these cliffs or banks have evidently been formed by the erosive action of the water upon a former sedimentary mound or hill, when its maximum depth was much greater than that of the present stream. Several such banks occur a little further on. Presently, the tower of Kingston Church looms into view, and at a spot where a bend in the river occurs, the stream increases in width, and there are several small islands. Here the steep bank on the left of the towing-path recedes from the river, and between it and the river there is a flat osier-covered area, which has evidently been permanently overflowed by the river in no very remote times. The appearance of that low steep cliff, and of the level area which reaches to its base from the river margin, leaves no room to doubt that it has been occasioned by the action of the stream when it was some feet deeper than it now is.

We now leave the river and take to the high road leading to the Kingston entrance of Richmond Park. The road is gradually higher and higher as the distance from the river is increased. Entering the park, we ascend what at first appears to be a steep-sided mound or hill, but on reaching its summit, it is seen to form part of the extensive range of elevated land whereon the park is situate. Viewing the landscape from this point, and looking over the town of Kingston, distant hill-ranges are visible, with lower hill-ranges between them, all of which appear to have a generally parallel direction; a circumstance in

itself indicative of their sub-aqueous origin. We take the path to the left, which lies along the border or margin of the elevation upon which we have ascended. Nothing can be more suggestive of former aqueous operations than the contour presented by this western side of that elevation, for there are bays, and inlets, and rounded promontories, just exactly of the kind that the action of the water would produce upon material like that of which the upper portion of the district consists. In some places the hill-side is very abrupt, but the degree at which it slopes is not everywhere the same. The extensive area lying between its base and the distant river appears from the height at which we are beholding it, to be flat, but in the walk just taken, it was found to consist of low, rounded mounds of different altitudes, such as would be produced in the course of time at the bottom of an extensive, but unimpetuous and slowly subsiding stream. Our route is still along the margin of the irregularly outlined elevation whose sides, in some parts, are formed into several steps or cliffs, the uppermost being, perhaps, thirty or forty feet high, and between each step or cliff is a nearly horizontal terrace of about as great a width.

We now arrive at a part of the park where a very extensive depression occurs—a depression that has not the character of a valley, but such as would, probably, be produced by the tidal flow and re-flow over it of the water when it had so far subsided as to leave always dry the higher parts of the extensive elevation on which the park is situate, and so as to cover this gently sloping depression only during the highest portion of each tide.

We then come to a spot whence may be surveyed the magnificent landscape described by Thomson:—

"Say, shall we wind
Along the streams? or walk the smiling mead?
Or court the forest glades? or wander wild
Among the waving harvests? or ascend,
While radiant summer opens all its pride,
Thy hill, delightful Sheen? Here let us sweep
The boundless landscape: now the raptured eye,
Exulting swift, to huge Augusta send;
Now to the sister hills, that skirt her plain;
To lofty Harrow now; and now to where
Majestic Windsor lifts his princely brow,
In lovely contrast to this glorious view,
Calmly magnificent; then will we turn
To where the silver Thames first rural grows.
* * * * * * *
Slow let us trace the matchless vale of Thames;
Fair-winding up to where the Muses haunt
In Twit'nam's bowers, and for their Pope implore
The healing god, to royal Hampton's pile,
To Clermont's terraced height, and Esher's groves.
* * * * * * *
Enchanting vale! beyond whate'er the Muse
Has of Achaia or Hesperia sung!
O vale of bliss! O softly swelling hills!
On which the Power of Cultivation lies,
And joys to see the wonders of his toil."

The well-known locality whence the scenery thus described by the poet is to be viewed, is the summit of the very steep declivity to the base of which extends the meadow that was first entered when the present short excursion was begun. It is, in fact, a portion of the extensive, steep-sided, and irregularly outlined elevation along whose margin the return journey from Kingston has just been made, and its appearance, considered in connection with the contour of the low-lying districts at its base, and with

the other incidents that have been noticed, is strikingly suggestive of the course of events to which the scenery of the Thames valley chiefly owes its characteristics.

Staines to Windsor.—So often do ancient river banks at various elevations, and other features indicating the former existence of a far larger stream than the present one, occur along the course of the Thames, that notice of them all would involve a wearisome repetition. The agreeable walk along the towing-path on one side of the river or on the other, from Kingston to Hampton Court and onward to Staines, will therefore be passed over without comment.

Resuming the journey at Staines Bridge and taking the path on the Surrey side of the river, the first object to be noticed is a rather large island, which is formed on the Middlesex side by a narrow semicircular branch of the stream on the one hand, and by the main river channel on the other. A little further on, just beyond a "London stone," which marks the civic boundary, there are other elongated islets, and then the land by the river is traversed by narrow water-courses, which divide it into irregular and isolated patches that are used for the growth of osiers. Several patches of reed are also to be seen above the surface of the water, indicating that accumulations of silt and sediment are occurring, and that sunken islands are being formed. These islets, and water-courses, and reed patches, considered in conjunction with the flat areas of fluviatile soil on either side of the river, seem all to indicate a gradual lessening of the depth and volume of water. Here again, on the Surrey side, the actual river bank is some

twelve or fourteen feet above the surface of the stream—in itself conclusive evidence to the same effect.

Having reached Belweir Lock, the town of Egham is seen over the meadows on the left, and the partially wooded slopes of Cooper's Hill lie before us "a little on the port bow." As viewed from this point that hill appears to be of an elongated shape, and to have a direction generally parallel with that of the river. Its sides seem not to be uniform, but to have such a conformation as would be imparted to them by a river current running with some violence, first against one part of them and then against another; the depth of water becoming meanwhile gradually reduced, and the direction of subordinate parts of the stream being thereby slightly altered.

Pursuing the walk along Runney Mead, Long Mead, and by Magna Charta Island, and passing the road to Old Windsor on the left, near whereto several water-courses, which still have free communication with the river, seem to indicate a site that the stream once overflowed, we arrive at the lock forming the entrance to the new cut which has been made for shortening the navigation; and at length, as Albert Bridge is approached, Windsor Castle looms into view. The general aspect of the district through which we have just passed, so far as it can be surveyed from this bridge, is suggestive of the same course of events as that before commented upon. The high lands of Windsor Great Park and some hill-ranges lying at a considerable distance in an opposite direction, would form, on the one hand and on the other, the margins or banks of the great stream which once flowed through this part of the Thames valley.

Taking the road to and passing by Datchet, we cross the Victoria Bridge and enter the Little Park of Windsor, which has the river for one of its boundaries, and whose flat and nearly level surface indicates that it once formed the bed of a large expanse of water. That suggestion is strongly corroborated by the steep cliff (now covered with foliage) above which the Castle rises with so picturesque a stateliness. It seems hardly open to question that the elevated land upon which the Castle is situate extended, in some far-off era, over the site of the Little Park, and that this cliff began to be formed when the water, then deeply submerging this part of the country, had so far subsided that it no longer flowed over that elevated area. The wide deep stream occupying the Thames valley at that period pursued the general direction taken by the river of to-day, but then (as now) the alteration or modification of its general condition, which gradually took place in consequence of an ever-continuous but almost imperceptible diminution of its depth and area, caused the stream slowly to acquire a slightly altered course at various points without affecting its general route, and to set with some force against the hilly obstructions that were in its way.

Maidenhead to Great Marlow, and upwards to Reading. —Some miles of ground may be again passed over without comment for the purpose of commencing a short excursion from the bridge at Maidenhead. Perhaps the most complete, and, at the same time, the most picturesque illustration of a former water-worn cliff to be met with along the entire course of the Thames, is that which exists between Maidenhead and Cookham, and is surmounted by the charmingly

situate ducal residence of Clifden. This nearly perpendicular chalk cliff, which is somewhat curved, and is of considerable height, has an extent of upwards of three miles, and is covered with numerous specimens of large and graceful British trees, amongst which the beech predominates. Opposite to it is an extensive area of nearly flat meadow land, beyond which, in the distance, are hills that are rounded and that seem to be of no great altitude. At the base of the cliff, in various places, are narrow flat strips of land.

Within a mile or so of Maidenhead Bridge the river is much branched by elongated islets, the existence of which seems to indicate a diminishing volume of water, and there appears to be a decided tendency for the channel to become choked up by numerous large patches of strong persistent reeds, showing that the sediment is accumulating in various places. Taking the form of submerged hillocks, these accumulations afford the very best facilities for the growth of such reedy obstructions. In some places, the actually navigable portion of the river is very narrow, and in the summer season has but little depth. Indeed, there cannot be a doubt, that if the artificial means of keeping the water back were removed from all parts of the river, the condition of the Thames, above the tidal range, would be little more than that of a mere streamlet.

Looking back from beyond the low wooden bridge of Cookham to the great beech-covered cliff of Clifden, it seems impossible to conclude otherwise than that the cliff acquired its steepness in consequence of a former great

current having been impelled against the hill in which it has been formed, as that current coursed onwards to the sea. The configuration of the entire district, when contemplated from the meadows just beyond the ivy-covered church of Cookham, seems to testify, most unmistakably, to the former existence of such a current.

The land on the left, beyond a distance of about half-a-mile from the river margin, is now seen to gradually rise, until it acquires a considerable height, and as the walk along the towing-path is pursued, the same high land by and bye presents a high and steep hill-side or cliff, between the base of which and the river are the flat meadows we are now traversing, and which are known as Cook-marsh Meadows. The hill referred to is called by the inhabitants of the neighbourhood Cook-marsh Hill, but in fact it forms part of a range of elevated land, extending, with a more or less undulatory outline, onwards beyond Great Marlow. A further portion of the same range is known as Winter Hill, beyond which it extends as a rather precipitous cliff for several miles. Presently the river recedes from this line of heights, near the part of it which is occupied by the ornamental beech-wood of Bisham.

Between this further part of the range and the line of hills on the opposite side of the valley, is a comparatively level expanse, at least two miles wide, the superficial part of which is composed of fluviatile materials, including an abundance of small chalk fragments. It is in this extensive former river bed that the present stream has here made for itself a channel.

It seems impossible to regard the various features of the neighbourhood, with reference to the probable causes which have produced them, without being convinced that they are all due to one gradually developing course of events. Manifestly, the high land in which those cliffs have been formed once extended further to the west, but by the action of a current, a portion of it was removed while the water was slowly subsiding. From the flatness, as well as from the nature of the materials of which the expanse lying between those distant hill ranges is composed, it is certainly to be inferred that this valley bed was once the bottom of an extensive collection of water, while the height of the actual river banks above the surface of the stream, even at its maximum level, shows that, since the Thames first formed its existing channel, its depth and volume have diminished.

The picturesque part of the cliff whereon is Bisham Wood, and opposite to which we arrive as soon as the spire of Marlow Church becomes visible from the river-side, bears a very close resemblance to the steep declivities by which the chalk hills in many other localities are marked, (the chalk hills near Petersfield, for instance, and especially the parts of them which are termed the "hangers,") and there can be little doubt that all such cliffs are the result of exactly similar aqueous operations. It must have been in very far-off times that those operations were in progress, if it has been, as there is every reason to believe it has, by a most gradual subsidence of water from this part of the earth's surface that the various characteristics under consideration have been produced. We have first to think

of the deposition of the chalk during a period when the climate of this region was, more or less, tropical, for it seems that the paleontological records of that marine deposit demonstrate that the climate was of that character. Then, when the water had so far subsided that a continent came into existence, and that the chalk hills stood out as islands in the midst of vast collections of fresh water similar, perhaps, to the American lakes of our own day, or, possibly, when those hills formed the banks of immense streams, by which the water flowing through such lakes was carried to the sea, the climate may have become more temperate. And how different must have been the appearance of the gigantic predecessor of the Thames of those ancient times, as compared with the river of our own period! In the August sunshine of our own days, the remaining little stream presents, at its sides, dense banks of wild-flower blossom. There are countless spikes of the tall purple loosestrife; the large plain flowers of the herb-willow display themselves in conspicuous abundance; the delicate undemonstrative heads of the meadow-sweet are sufficiently numerous to give prevalence to its delicious odours; yellow panicles of the erect common loosestrife, and of a species of Saint John's wort, add considerably to the brightness of that floral river border; while very many other plants, including the common yellow flea-bane, the inconspicuous comfrey, the large light pink heads of the hemp agrimony, and the white umbels of the mille-foil, contribute unstintingly to the general effect. But imagination would be hardly taxed if it were called upon to describe, or even to conjecture, what was the floral vegetation

of those remote times, when, probably, our country formed part of a continent, and when its widest valleys, now lying between distant high hill-ranges, formed the river channels for the outflow of such fresh-water lakes as those referred to. Our national history comprises a period by no means inconsiderable. There is no doubt that generations of our forefathers have made the river a general highway for trade and pleasure. Large vessels laden with merchandize, and small boats freighted with joyous young life, have navigated the ever and ever on-flowing stream. But in how far-off an era of antiquity it was that the river current had so much greater a depth than at present, or what were its various characteristics, no one can tell, for the geological records of our world's earlier life have not yet been so far deciphered.

Reading to Pangbourne.—Although a very great diversity of scenery is presented to the notice of the rower or pedestrian in prosecuting such a journey as that which is now in progress, yet those characteristics of superficial outline which are the special object of attention on the present occasion are repeated over and over again. It is unnecessary, therefore, to dilate upon more than a few of them, and various portions of the route are therefore passed over, at frequent intervals, without observation. The river usually, on one side or the other, flows near or against hilly elevations of some kind, but it sometimes meanders through level districts of considerable extent; and although its channel is for the most part narrow, yet, in some hilly localities its waters are more dammed up than in others by the convergence of higher hills. Thus,

towards Henley, it widens considerably and forms a fine expanse or reach, in consequence of the natural and artificial impediments in the way of its on-flow a little further down. Abstaining, however, from futher observations till we arrive at Reading, and taking the towing-path near the bridge at that place, we find ourselves opposite to the village of Cavesham, in a rich meadow which presents, in the middle of this month of May, (for that is the time of the year when this part of the journey is made,) a large area of glittering yellow and fresh green herbage. The meadow itself is nearly or quite flat, and it is only its very slight and almost imperceptible rise from the river side that takes from it the character of an absolute level. At this period, the surface of the stream is some three or four feet below that of the meadow; hence, the vertical section of the actual river bank is exposed to view, and it shows that the soil is composed of materials such as would be cumulatively deposited at the bottom of a quiet expanse of water or of a gently flowing stream. From the flatness and approximate levelness of the meadow, as well as from the character of the soil, the inference is, of course, unavoidable that it was for some time covered with water, and formed the bottom of such an expanse, or of a current which had not, at this place, so swift a motion throughout its entire depth as to prevent the deposition and accumulation of such fluviatile materials. It is well known that the velocity of a river is greatest at the surface, and is graduatingly diminished towards the bottom; and it may be seen, and, in fact, it is a matter of not uncommon remark, that some parts of every stream are comparatively

still and tranquil, partaking of the character of a lake. A lake, in fact, is only a large accumulation of water lying in a river's course, and its existence is due to the special configuration of the district wherein it is situate, which impedes the regular out-flow of the whole current, and permanently dams up a portion of its waters. It is because a valley of any extent, greater or less, becomes narrowed at its lowest extremity by the convergence there of the hill or mountain sides by which it is formed, that the waters of a river flowing through it acquire the dimensions of a lake. The channel of on-flow does not permit the whole of the water brought down the river to continue its seaward course. It hence becomes dammed up, until it has risen to a level at which there is a line or opening between the hill or mountain sides sufficiently wide to permit only just that quantity of water which enters the valley to be discharged through its lower extremity. And when a regimen has become thus established, a current continually flows through the central part of the lake, taking off the same quantity of water as that which comes from above, and maintaining the lake at an approximately established level. Such may be seen to be the cause to which all lakes lying in a river's course owe their origin.

Now we have only to glance round the immediate neighbourhood of Cavesham to see that the configuration of the district is exactly such as would be conducive to the accumulation of large tracts of water, supposing there to have been formerly existing a stream of much greater magnitude than that of the Thames of to-day. There are

low hills forming valleys of greater or less extent between them, and whose sides, at places, so converge together, that if a stream of any size had flowed through those valleys, its waters must have become thus dammed up. And that the beautiful meadow through which we are now supposed to be walking once formed the bed of such an accumulation of water there cannot be a doubt. Looking directly across the river, there is to be seen a nearly vertical cliff, between whose base and the margin of the stream there lies a slightly sloping bank. The cliff has evidently been formed by the removal of a portion of a hill, for its upper edge is curved, and its height is not the same in all parts of it, and, in fact, it can be seen a little farther on to be the vertical section of a hill. The river recedes from it, and its upper edge slopes downwards into a depression, showing that there is a valley between the hill of which the opposite cliff is a section, and another hill of greater altitude, a portion whereof has been also removed, leaving a similar section, continuous with the other, exposed to view. Thus there is a continuous cliff at an increasing distance from which the river now flows, and between whose base and the river is a nearly horizontal bank which ultimately expands, by the increase in the distance between the river channel and the cliff, into the dimensions of a meadow. The conformation of the district already remarked upon indicates the cause to which that cliff owes its origin.

Continuing our spring-tide walk by the side of the stream, whose wind-ruffled surface seems to be covered with myriads of dancing sun-lit spangles, we come to a part of the river where it is divided into two channels by an

islet having an elongated outline. To the question, "How came that islet to be formed?" an answer at once suggests itself in circumstances already dilated upon. Almost every Londoner knows well enough that islets of this description occur in all parts of the Thames from Chelsea upwards. Evidently they have been formed in consequence of the depth and volume of the larger river having gradually diminished, and of its having formed a branching channel for itself in places where slight elevations in its former bed gave a somewhat deflected direction to subordinate parts of the main stream.

A journey through these meadow lands at this time of the year is attended with very exhilarating circumstances. In the brightness of the afternoon sunshine the early foliage of the many kinds of trees, and the various sorts of flowering herbage in the fields, are seen to the greatest advantage. The intermittent breeze brings frequent tokens of spring time in the form of the sweetest of pure country odours. Some hedges and isolated trees of the May are entirely covered with the chastest of white blossom. Bordering various parts of the river, and partly overhanging it, many a horse-chestnut throws the shadow of its stately form upon the water, and sustains upon its fresh-looking pyramid of verdure a methodical though most ornamental array of delicate-floretted flower cones. With these silent manifestations of the full inset of spring-tide, there lack not other tokens of a more animate kind; for, though "family arrangements" are no doubt keeping most of the feathered tribes at home upon their nests, a few are still in song, and some are otherwise actively enough em-

ployed. Swallows are pursuing their insect prey with a swift motion that would be arrow-like but for the frequency and suddenness of its change of direction. And in another department of life, the business-like hum of an occasional bee indicates that his period of profitable industry has also arrived.

But without further remark upon the numerous incidents which are displayed at every step of our journey, let us resume our observations upon the contour of the neighbourhood through which we are travelling. When the observer has once become accustomed to note and reflect upon the appearances presented by the superficial conformation of the country, he then sees in the shape and situation of every naturally formed bank, and mound, and hill, and in the features characterising every depression and valley, the most striking and convincing evidence of that gradual course of events from which have emanated those varieties of outline that now give to the landscape so much picturesqueness and beauty.

A distance of some three or four miles has been just travelled. Several more islets have been passed. At length a part of the Thames valley is reached where high hill-sides approach near to each other, and where there must have existed in ancient times, not exactly a "gorge," but, so narrow a passage that a considerable degree of erosive power was exercised by the great concentrated volume of water which then flowed through the valley. Accordingly, the hill-sides are steep, and in various situations and at different heights they exhibit cliff-like declivities. We arrive at a place where a declivity of that

kind so nearly abuts upon the river, that a nearly horizontal bank of only a few yards wide exists at one spot between its base and the river margin. It is here that the "Roebuck" Inn is perched, at an elevation of some fifty or sixty feet above the public pathway by the river, and where a portion of the Great Western Railway has been constructed. From this place, looking obliquely across the river in an up-stream direction, the beautifully wooded hill-side of Maple Durham is seen to recede from the river channel, so as to leave between its base and the river an area of flat meadow land, which becomes wider in the upward direction of the valley. Crossing by the ferry and taking the path which diverges from the river, in order to avoid the water-courses that intersect the meadow, the configuration of the district is again seen to be most plainly suggestive of the aqueous operations to which it is due.

On arriving near the picturesquely situate water-mill, we are re-ferried over the river, and resuming our journey, we emerge upon an extensive open tract of country, which is bounded on the opposite side of the winding stream by an almost semicircular range of chalk hills. It is upon looking back upon the route we have traversed that the Thames valley at Maple Durham is seen to be very conspicuously contracted, and to form there a kind of throat or "gorge," which suddenly widens out into the open expanse we are now beholding. Those opposite hills consist of a more or less undulating range. On this side, and nearly facing the steep hill-side of Maple Durham, is a large rounded elevation, which seems to form a sort of terminal headland belonging to heights that appear as though a

great current had once set against them. The configuration of the district is suggestive of one portion of the current having been forced through the throat of the valley whence we have just emerged, while another large portion was turned aside in a westerly direction. The opposite semicircular range bears the indications of its having been worn and eroded by such a current, to which a tumultuousness of condition was imparted by the obstructions presented to its regular onflow.

The journey is now by the banks of the stream which flows nearly from west to east at a greater or less distance from that opposite hill-range, and having a wide open tract of country to the south and south-west, the riverside meadows being nearly level; and at length we arrive in the neighbourhood of Pangbourne, where the scenery is of the most delightfully picturesque description. From this interesting locality, however, some miles of ground will be passed over without observation.

Wallingford to Clifton Hampden.—The next stage of our journey commences near the ancient town of Wallingford, in the "King's Meadow," which lies on the upper side of the bridge over the river at that place. The first object to be noticed is a strip of land forming the bank of the river, but it is isolated from the meadow by a water-course ten or twelve feet wide, into which water from the river freely enters. It is, in fact, known as the ait, and in its water-sodden soil osiers are grown. The origin of this particular ait, as of all the others, seems clearly attributable to the shallowing of the water, and would not here call for remark but for the

purpose of comparing it with a low hill which bounds the meadow through which we are journeying. This hill is parallel with the river, and is distant about a third of a mile from it, and up towards it "King's Meadow" gently slopes. It would form a bank of the river, if this part of the stream were fifteen or twenty feet higher than it now is, very much like the "ait" or isolated slip of land which now actually borders the river. The contour of the two banks seems plainly to show that it is due to exactly the same course of events—namely, the gradual shallowing of the water. On the Oxfordshire side again, the country is formed of similar low rounded hills, right up to the chalk range of the Chilterns, some three or four miles distant.

Crossing the river by a ferry at Crowmarsh, we enter the meadows beyond that place, and presently it is to be observed that the river flows at the base of a hill on the Berkshire side, which becomes higher and higher, and has an increasing degree of steepness as the bridge at Shillingford is approached. Passing over that bridge, we are brought nearly opposite to a vertical cliff of forty or fifty feet high, into which that steep hill-side is resolved. Then between the cliff and the river is a steeply sloping area, which presently increases to considerable dimensions in consequence of the recession of the river channel from the line of hill in which the cliff has been formed. Along the higher part of this area is a rough country road, which conducts us by a very picturesque and partly wooded route, towards the village of Little Wittenham, some two or three miles further on. Whatever may have been the period when were deposited the materials constituting the line of

hill wherein the cliff has been formed, of this there cannot be a doubt, namely, that the lower part of the hill-range has been subjected to the eroding operations of a powerful current. The conformation of the cliff, and of the locality in which it is situate, present the most palpable signs of there having occurred aqueous operations of that description, and of a most gradual subsidence of the great stream which once set with considerable violence against the hilly obstructions here lying in its way.

At length the cliff becomes merged into the general slope of the hill-range of which it forms a section, and from the road we are travelling, we have a good opportunity of surveying the contour of the district. On this Berkshire side of the Thames, the country consists of an undulating hill-range, which rises higher and higher towards the village of Little Wittenham, and it culminates in an elevation of considerable altitude, whereon are situate the two conspicuous and ornamental clusters of beech trees known as the "Wittenham Clumps." From the summit of this hill, upon which we have ascended, a very wide expanse of country is visible. The hill is the highest of any in the neighbourhood, and it stands prominently out in the landscape as the terminal headland of the undulating range of which it forms a part. To the east and south-east lies the long line of the Chilterns, and viewed from this commanding height, the aspect is suggestive of the whole region having been so deeply submerged, that the headland once stood out as an island in the midst of a great stream which was divided by the hill-range to which that elevation belongs. Under those circumstances, the hill would

be freely exposed to the continual set of the stream, and would thereby acquire the degree of steepness which now distinguishes it. The route of the Thames still continues to be diverted by this very hill-range from a direct southerly to an easterly course. In the vicinity of the village at the base of the hill, the surface of the land is very irregular, and besides being broken up at the lower part by several water-courses, having more or less direct communication with the river, there are cliff-like banks of various kinds. So commanding and yet so isolated are the spots upon which the beautiful beech clumps now flourish, that they seem to have been selected for a military post. Tokens are still visible of what appear to be artificial earth-works, not only upon the double mounded summit of the hill, but about the village at its base, which is situate in a sort of corner-land seemingly well adapted for a military station.

Resuming the towing-path, a retrospect of the district we have been surveying from a height confirms the impressions before received. Former river banks in low rounded hills closely abutting upon the river, and all the features before remarked upon, recur over and over again. At Clifton Hampden Bridge, is another conspicuous example of a high eroded bank, against which the present stream is still impelled. From the nature of the materials composing the elevation in which that bank is formed, it is evident that we are entering upon a part of the country where the geological formations are of a different character from that of the route just traversed.

Culham—Abingdon—Oxford, &c.—Instead of follow-

ing the river, we will now for a mile or two take the road towards Abingdon. A little before arriving at the village of Culham, a most extensive prospect of the surrounding country may be surveyed. Looking towards the south, two extensive ranges of hills, the Chilterns on the one side, and a line of elevations running nearly east and west on the other, ultimately trend round to the south, and seemingly converge towards each other in the direction of Pangbourne and Reading. In the foreground stands the hill near Wittenham.

About three-quarters of a mile to the south-east of Abingdon—namely, near Culham, there commences what at first appears to be a low hill-range of eighty or a hundred feet high, but on inspecting it, it is found to be a steep bank, and to have characteristics such as have been frequently remarked upon in the foregoing pages. Manifestly it once formed the bank of the river itself. At its base is a nearly flat meadow much intersected with water-courses. Nothing could be plainer than that this elevation, which in some parts is precipitous, once formed such a bank. It is continued by Warren Farm on to Nuneham Park, where it is ornamentally overgrown with trees. From Nuneham Courtney to Oxford there occurs nothing of a conspicuous character. Towards that city the hills that lie beyond the meadows bordering the river, seem to attain a considerable elevation.

At and beyond Midley, that is, within a short distance of the University, the river acquires a very interesting appearance, for the water is held back by lock and weir, and is of considerable width. Although it seems to have be-

come subdivided by the conformation of the land in the neighbourhood of Oxford, yet there cannot be a doubt that the line of hills upon the west which is terminated by Witham Hill determined this portion of the river's course. Similarly, the range of high land between Farringdon and that hill of Witham has determined the course of that further part of its journey. It flows *from the south to the north* from Langley Weir near Fyfield, towards Witham; it then flows round that hill and pursues an almost *southerly course* past Oxford as far as Nuneham, where it is turned westward by the old river bank already commented upon as lying between that place and Culham.

Lechlade—Cricklade—Thames Head.—It would be tedious and profitless to dwell in further detail upon the indications of the former existence of a much larger stream than the Thames of our day, which are to be met with in the higher parts of the river. A few further remarks, however, may be made respecting the remainder of the journey we are pursuing. The country between Farringdon and Lechlade is of considerable altitude. It includes Badbury Hill and another hill of about the same height, which forms part of Buscot Park; and although there are several undulations and depressions in the intermediate distance, yet it is not until the village of Buscot is reached that there occurs a descent to the nearly level river-side meadows about Lechlade. It is at that place that the Thames may be said to terminate, for near it several rivers are united into one stream.

Upwards by Cricklade, to the most elevated part of the river, characteristics similar to those before dilated upon

recur. The stream, however, becomes insignificant, and its importance has been very much diminished by the use to which the springs in which it is commonly supposed to originate, have been put. "Thames Head," for we have now arrived at the spot so called, is situate some three miles distant from the old Roman town of Cirencester, but it has become somewhat of a misnomer, for it is only in times of abundant rain that the ancient fountain-head of the river proclaims itself. The springs from which its very first portion is derived are situate in Trewsbury Meadow, which owes its name to its proximity to Trewsbury Castle. They have now ceased to send forth their limpid streams, excepting when there is a copious rainfall, for within about 200 yards of them is the well of sixty-three feet deep, whence the water, which of yore supplied those springs, is pumped by a powerful steam-engine into the Thames and Severn Canal, the most elevated part of whose route is there situate. The waters which formed the original source of the river are prevented from reaching the surface of the land in the natural manner, and as it happens that there is a greater amount of canal traffic towards the Severn than the Thames, a proportionately larger amount of water finds its way into the western river. The meadow in which are or were the springs, has an elevation of about 376 feet above the level of the sea at the river exit at the Nore. The country immediately around is of a deeply undulating character, and seems to be formed of the rounded tops of many hills. The meadow itself occupies a depression between two such hill-tops, or rather, it is what is in the neighbourhood called a "bottom," which winds round

the hills, as it gradually descends to a lower level and becomes merged into a regular valley. Raised across the meadow is one of the old Roman roads that radiate from Cirencester, and within a short distance of the spot occupied by the lowest of the Thames Head springs the proper channel of the river begins. In summer this channel is quite dry in consequence of the water being drained off in the manner already pointed out, but sometimes when rain prevails, not only is it occupied by its own natural stream, but the meadows through which it winds become deeply inundated. In the present month of August the channel is quite dry for a distance of fully two miles; but that the stream which sometimes fills it has a considerable velocity, is shown by the channel sides or banks being in some places bare of vegetation, and exhibiting shallow sections of the soil wherein it has been formed, and which is in a great measure composed of the shaly fragments of the oolitic rock constituting this part of the country. The markings of a former permanent stream, which had a far greater depth and volume than the existing one, are to be seen at various places along the hill-sides between which the river of our times commences its long journey to the sea.

General review of the journey, and the course of geological events indicated by the various features which have been noticed.

Let us now briefly review some of the principal facts which have presented themselves to notice in the course

of the journey we have made from the Nore to Thames Head, and note two or three important geological deductions to which they irrefutably point.

First of all, then, the actual banks of the present stream are more or less vertical, and in many places they are of such a height as to be considerably above the surface of the river when at its greatest altitude in times of flood.

Next.—Throughout the whole distance travelled by the Thames, there are, sometimes on one side of the river, sometimes on the other, and sometimes on both sides, low and nearly level areas of greater or less extent, which consist of materials that are manifestly of fluviatile origin. Evidently the present river channel has been formed since that fluviatile deposit took place.

Third.—Those nearly level areas often extend to the bases of cliffs or banks of various altitudes, which are, in fact, vertical sections of hilly elevations that, in many different cases, consist of different kinds of material, and belong to very different geological formations and periods.

Fourth.—The hills wherein such banks have been formed are sometimes of considerable height, and it frequently happens that their steep cliff-like sides form the valley through which the Thames pursues its seaward course; sometimes they almost or quite abut upon the river.

A few of the localities from which the foregoing remarks have been derived may be again mentioned. There is Thorpe Cliff near Shoeburyness formed of a recent deposit. Southend Cliff is a section of a hill composed of the sub-marine material known as the London clay. There is the vertical chalk cliff on the

Kentish side of the river, which has given its name to the village of Cliffe situate near it. A chalk eminence surmounted by a sandy deposit occurs at a conspicuous bend of the river at Purfleet. The extensive elevation, on a part of whose embayed margin is the National Observatory at Greenwich, is found to consist in a great measure of light friable soil, with which vast numbers of black flint pebbles are more or less intermixed, and which are often seen to have been deposited in strata. Richmond Hill is a portion of a very prominent elevation. Another elevation of an important character is surmounted by the grand old castle of Windsor. High chalk cliffs are conspicuous between Maidenhead and Cookham and onward towards Great Marlow, and the country about Maple Durham and Pangbourne is similarly characterized. The cliff at Shillingford terminating in the very bold headland near Little Wittenham next calls for remark. A decided former river cliff occurs near Abingdon, reaching from Culham to Nuneham Wood. We then come to the hill of Witham, beyond Oxford, which has been the occasion of the bend there made by the river. The high land near Buscot, overlooking the extensive meadows at Lechlade, and which lies a few miles beyond Farringdon, and is a continuation of the elevations in the neighbourhood of that town, is the next important feature of the route before we pass over a distance of several miles, and finally extend our attention to the locality near Cirencester, where the river takes it rise.

Throughout the entire course of the river, cliffs of less altitude than those occurring at the places just

mentioned are to be continually met with. In fact, the general characteristics exhibited in the conformation of any one district through which the river flows, are the same as those by which every other such district is marked, excepting the geological formations to which those various portions of the route belong, and they all concur in pointing to one and the same course of events. That the condition of the river has been altered since its existing channel began to be formed, is shown by the elevation of the actual river banks above the maximum height of the river's surface. The supposition that the diminution in the depth and volume of the stream which has evidently taken place, is attributable *only* to a reduced amount of land drainage, is precluded; for unless it had resulted from a lowering of the sea level at the river exit, the characteristic under consideration could not have been produced in the lower reaches of the Thames, which are freely accessible to the sea, and where its depth, therefore, is altogether dependent upon the sea level.

The occurrence of the nearly flat areas of fluviatile soil lying on either side of the river channel, and of the vertical cliffs to which they so often extend, unmistakably point to the former existence of a stream of much greater depth and magnitude than the river of our times, and the cliffs in the higher hills which have been mentioned indicate that a still larger stream once occupied that which is now the Thames valley.

As all parts of the country traversed by the river consist of sedimentary rocks of different sorts, of course there cannot be a doubt that they were covered by a con-

siderable depth of water during some former period. The nature of the materials composing those rocks, and their absolutely undisturbed state, show conclusively, however, that it was by no upheaving force that the region in which they are situate became elevated above the sea; and the condition of the present river channel, formed as it is in the bed of a previously existing larger stream; the old river banks of various heights to be met with all along the route we have journeyed, and the general superficial contour of the districts through which the river flows, seem to demonstrate irrefutably that the element which thus prevailed *became most gradually reduced in depth*, and by and bye subsided into the condition of extensive inland seas and gigantic rivers, which then came to be divided into smaller lakes and streams, until ultimately the dry land in our part of the world acquired the character it now possesses.

It is not intended on the present occasion to enter upon a consideration of the causes whereby the level of the sea becomes altered in different parts of the world relatively with the dry land, although it seems to be capable of demonstration that that effect results from the operation of astronomical laws and influences. The facts however which have presented themselves to our notice in the journey we have taken seem to indicate the course of the events which have occurred. The vast accumulations of marine sedimentary deposits prove that the sea deeply prevailed over portions of the earth's surface which have now a great altitude above the sea level. Those marine deposits were afterwards subjected to the erosive action of currents.

Newer deposits in the meantime were formed, and they were afterwards similarly subjected to abrading and eroding influences. By and bye parts of the earth's surface emerged above the water, and during the process of emersion some districts were entirely denuded of their sedimentary covering, so that, in some localities, the more primitive structure of the rocks composing the earth's crust became exposed—a result which seems to have been mistaken by geologists for the forcible extrusion, by volcanic agency, of the older rocks through sedimentary formations. Upon extensive regions which thus emerged out of the ocean, there were then probably formed vast accumulations of fresh water, similar perhaps to the existing American lakes, whose overflow was discharged by means of rivers like the Amazons and Mississippi of our own days, having in some parts of their route a breadth of many miles. In consequence of the same regions continuing to attain a greater elevation above the sea level, the fresh-water accumulations would gradually become more rapidly discharged into the ocean. The gigantic rivers of those ancient times would then become gradually reduced in depth and area, and afterwards be divided into separate streams by lesser hills and hill-ranges existing in the midst of those greater valleys which had formed the main channels of outflow.

In course of time these divided streams in their turn became reduced and subdivided. In some districts the larger currents probably committed ravages amongst the older sedimentary rocks, even while they were elsewhere depositing mounds and hills of their own sediment, and

it is not difficult to imagine that such vast volumes of water would excavate for themselves, through the formations of some localities, passages as wide as or wider than those that now exist as the Dover Straits, or the Solent, and, by their constantly flowing volume and their great velocity, altogether exclude the sea therefrom; but when they had become greatly diminished in depth and volume, then such of those channels as had a depth below the level of the ocean would become occupied by the water of the sea, and would acquire the condition of intercommunicating branches of the ocean, or straits lying between the mainland of a continent and the islands near its vast river embouchures.

Such, then, would seem to be the course of events which, upon actually examining the districts traversed by the Thames on its way to the ocean, we may reasonably suppose to have taken place in this part of the world. Just as the shoals and banks lying at the river entrance and around our coasts, between the extreme limits of high and low water, are alternately covered and left dry by the daily tides, so do the different portions of the globe's surface gradually become submerged beneath, and then raised above the ocean by means exactly similar to those whereby the tidal alternations are occasioned. In the one case effects, that by comparison may be called microscopical, are produced in a tidal day of twelve hours duration; in the other case, during a period of perhaps twenty-six thousand years, the entire face of the globe is renovated and transformed. Valleys are exalted and hills made low; mountains are carried into the midst of the sea; water-springs, rivers, and seas are dried up; and the

mysterious labyrinths, once lying under the vast depths of the ocean, are brought to view. The fruitful field is converted into a sandy desert, and that which was a vast arid expanse, with but an oasis here and there to relieve its hot, dreary monotony, gradually becomes irrigated with fertilising streams, and acquires a condition of abundant fruitfulness.

It seems to be strikingly in accordance with what are conceived to be the great laws or principles to which all nature is subordinate, that a course of events like this should take place. As far as can be perceived, it is in virtue of the law or principle manifested in gravitation, not only that vapour is first formed into dew and rain, and is then impelled towards the sea, but also that the condition of the mighty ocean itself is determined and abidingly maintained. It is gravitation that causes a pebble to return to the earth when thrown into the air, and that also rules the motions of the planets. And so, even if the fact were not scientifically demonstrable, do the analogies of nature seem to justify the belief that the operation of one and the same great law or principle, produces as well the daily tidal alternations, as those vastly greater changes of level which are revealed to us by the internal structure and the fossil records of the rocks, by the general superficial contour of the dry land, and by such particular indications as those which are traceable throughout the winding route pursued by the Thames from its source at Thames Head, to the estuary wherein its waters become commingled with those of the great ocean.

THE BOULDER FORMATION.

The boulder formation, as described by Sir C. Lyell and Hugh Miller —The proof it affords of deep sea currents having flowed over the parts of the world where the boulder rocks are now found—The transference of the water from those sites was an effect produced by the astronomical influences to which the daily tides and ocean currents are due.

AMONGST the many interesting questions which properly belong to the geological branch of science, the one which concerns the origin of continents and islands seems entitled to a prominent place. It still remains unsettled, however, although several attempted solutions have been brought forward from time to time.

One important link in the chain of evidence which bears upon the subject consists of the fact, that all the present dry land has been submerged beneath the ocean during some former era in our planet's history—a fact that is most plainly attested by the structure, the constituent materials, the stratification, the fossil contents, and the superficial contour of the "aqueous rocks," whose existence is traceable over all the known parts of the world. And further help towards an elucidation of the inquiry is afforded in a very considerable degree by the characteristics of the portion of those sedimentary deposits which embrace the "boulder formation."

Let us see what are the distinguishing features of the group of rocks to which that appellation has been given by geologists, and then, noting the inferences of a general character that are deducible from them, let us apply those inferences to the question as to how different parts of the globe's surface came to be elevated above the sea level.

The following is Sir Charles Lyell's description of the boulder formation as extracted from his *Manual of Elementary Geology* :—

"The portion of it which extends from Finland and the Scandinavian mountains to the north of Russia, and the low countries bordering the Baltic, and which has been traced southwards as far as the eastern coast of England . . . consists of mud, sand, and clay, sometimes stratified, but often wholly devoid of stratification for a depth of more than a hundred feet. . . . It generally contains numerous fragments of rocks, some angular and others rounded, which have been derived from formations of all ages. . . . Some of the travelled blocks are of enormous size, several feet or yards in diameter; their average dimensions increasing as we advance northwards.

"Although a large proportion of the boulder deposit or northern drift, as it has sometimes been called, is made up of fragments brought from a distance, and which have sometimes travelled many hundred miles, the bulk of the mass in each locality consists of the ruins of subjacent or neighbouring rocks; so that it is red in a region of red sandstone, white in a chalk country, and grey or black in a district of coal and shale.

"The fundamental rock on which the boulder formation reposes, if it consist of granite, gneiss, marble, or other hard stone capable of permanently retaining any superficial markings which may have been imprinted upon it, is usually smoothed or polished, and exhibits parallel striæ, and furrows having a determinate direction. This direction, both in Europe and North America is evidently connected with the course taken by the erratic blocks in the same district, being from north to south, or if it be twenty or thirty degrees to the east or west of north, always corresponding to the direction in which the large angular and rounded stones have travelled.

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"The recent polishing and striation of limestone by coast ice, carrying boulders even as far south as the coast of Denmark, has been observed by Dr. Forchhammer, and helps us to conceive how large icebergs, running aground on the bed of the sea, may produce similar furrows on a grander scale. An account was given so long ago as the year 1822, by Scoresby, of icebergs seen by him drifting along in latitudes 69° and 70° N., which rose above the surface from 100 to 200 feet, and measured from a few yards to a mile in circumference. Many of them were loaded with beds of earth and rock. . . . A similar transportation of rocks is known to be in progress in the southern hemisphere, where boulders, included in ice, are far more frequent than in the north. . . . A large proportion of these floating masses of ice are supposed not to be derived from terrestrial glaciers, but to be formed at the

foot of cliffs by the drifting of snow from the land over the frozen surface of the sea.

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"That the erratics of northern Europe have been carried southward cannot be doubted; those of granite, for example, scattered over large districts of Russia and Poland, agree precisely in character with rocks of the mountains of Lapland and Finland; the distance being 800 and even 1,000 miles from the nearest rocks from which they were broken off; the direction having been from N.W. to S.E., or from the Scandinavian mountains over the seas and low lands to the south-east.

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"It was stated that in Russia the erratics diminished gradually in size, in proportion as they are traced farther from their source. The same observation holds true in regard to the average bulk of the Scandinavian boulders when we pursue them southwards from the south of Norway and Sweden, through Denmark and 'Westphalia.' . . . The greater . . . the volume of the iceberg, the sooner would it impinge upon some shallower part of the sea, while the smaller and lighter floes, laden with finer mud and gravel, may pass freely over the same banks and be carried to much greater distances.

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"The northern drift of the most southern latitudes is usually of the highest antiquity. In Scotland it rests immediately on the older rocks, and is covered by stratified sand and clay. . . . The distance to which erratic blocks have been carried southward in Scotland, and the course

they have taken, which is often wholly independent of the present position of hill and valley, favours the idea that ice-rafts, rather than glaciers, were in general the transporting agents.

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". . . the boulder formation displays almost everywhere . . . a strange heterogeneous mixture of the ruins of adjacent land, with stones, both angular and rounded, which have come from points often very remote. Thus we find it in our eastern counties . . containing stones from the silurian and carboniferous strata, and from the lias, oolite, and chalk, with all their peculiar fossils, together with trap-syenite, mica-schist, granite, and other crystalline rocks."

On the Norfolk coast the drift " consists of clay, loam, and sand, in part stratified, in part devoid of stratification. Pebbles, together with some large boulders of granite, porphyry, greenstone, lias, chalk, and other transported rocks, are interspersed, especially through the till. That some of the granite and other fragments came from Scandinavia I have no doubt, after having myself traced the course of the continuous stream of blocks from Norway and Sweden to Denmark, and across the Elbe, through Westphalia to the borders of Holland. We need not be surprised to find them reappear on our eastern coast, between the Tweed and the Thames, regions not half so remote from parts of Norway as are many Russian erratics from the sources whence they came."

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The erratics observed in Lancashire, Cheshire, Shropshire, Staffordshire, and Worcestershire " have come partly

from the mountains of Cumberland, and partly from those of Scotland.

"On the mountains of North Wales the 'northern drift' reaches its greatest altitude.

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"That there is some intimate connection between a cold or northern climate, and the various geological appearances now commonly called glacial, cannot be doubted by any one who has compared the countries bordering the Baltic with those surrounding the Mediterranean. The smoothing and striation of the rocks and erratics are traced from the sea-shore to the height of 3,000 feet above the level of the Baltic, whereas such phenomena are wholly wanting in countries bordering the Mediterranean; and their absence is still more marked in the equatorial parts of Asia, Africa, and America; but when we cross the southern tropic and reach Chili and Patagonia, we again encounter the boulder formation between the latitude 41° S. and Cape Horn, with precisely the same characters which it assumes in Europe. The evidence as to climate, derived from the organic remains of the drift, is . . . in perfect harmony with" those conclusions.

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"In the western hemisphere, both in Canada and as far south as the 40° and even 38° parallel of latitude in the United States, we meet with a repetition of all the peculiarities which distinguish the European boulder formation."

The account of the same group of rocks, given by Hugh Miller, is to a similar effect. It is thus described by him in his *Lectures on Geology*:—

"The boulder clay is found in Scotland, from deep beneath the sea-level, where it forms the anchoring ground of some of our finest harbours, to the height of from six to nine hundred feet along our hill-sides. The travelled boulders, to which it owes its name, have been found as high as fourteen hundred feet. Up to the highest of these heights icebergs at one time operated upon our Scottish rocks. Scotland, therefore, must in that icy age have been submerged to the highest of these heights. It must have existed as three groups of islands — the Cheviot or southern group, the Grampian or middle group, and the Ben Weavis or northern group."

Adverting to "the direction of the icebergs which went careering at this period over the submerged land," Hugh Miller continues,—"as shown by the lines and furrows which they have graven upon the rocks, their general course, with a few occasional divergencies, . . . was from west to east. It is further a fact exactly correspondent in the evidence which it bears, that the trap eminences of the country—eminences of hard rock rising amid districts of soft sandstone, or still softer shale—have generally attached to their eastern sides, sloping *tali* of the yielding strata out of which they rise, and which have been washed away from all their other sides.

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"This westerly direction of the current seems to be exactly that which . . . might be premised.

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"The point at which, in the existing state of things, the Gulf stream and the Arctic current come in contact is

that occupied by the great bank of Newfoundland. . . . "The number of boulders and the quantity of pebbles and gravel strewed over the bottom of the western portions of the Atlantic, in the line of the Arctic current, from the confines of Baffin's Bay up to the 45° of north latitude, must be altogether enormous. . . .

"It is as little improbable that" the point where the Gulf and Arctic currents come in contact "should have met in the remote past some two or three hundred miles to the *west* of what is now Scotland, as that in the existing period they should meet some two or three hundred miles to the *east* of what is now Newfoundland."

Now the characteristics of the boulder formation, as described in those extracts, not only establish beyond a doubt, that the sites whereon deposits belonging to the formation are now situate, were once submerged beneath the water, but the following inferences seem to be also clearly deducible from them.

(1) In the remote times when the sand and mud of the boulder rocks accumulated upon any part of the sea-bed, the water by which those materials were deposited had the character of an oceanic current.

(2) During the period that any such current existed, it continuously flowed in nearly one general direction.

(3) The water which thus covered the sites whereon the boulder rocks were deposited, gradually shallowed, and the sea-bed beneath it ultimately became elevated above the sea surface, and so acquired the condition of dry land.

The facts and explanations which have been quoted

plainly show, that the principal characteristics of the "northern drift" or "boulder formation," from which its appellation is derived, are due to the instrumentality of icebergs that were borne from Arctic regions to more southern latitudes by oceanic currents which flowed continuously in a direction from about N.W. to S.E.

It appears, for instance, that innumerable blocks and fragments of granite and other materials, originally portions of rocks existent in northern latitudes, are now to be found at various distances from the localities whence they were derived, some being strewed over the surface of the present dry land, others being embedded in some of the sedimentary deposits of which the upper parts of the present dry land consists.

Such a disposition of the boulders over a determinate route of some hundreds of miles in length, but not extending very far towards equatorial regions, and unquestionably effected when that route was submerged beneath the sea, could only have been accomplished by means like those that are accomplishing similar results at the present day, namely, by icebergs, which were carried into temperate latitudes by an established oceanic current that flowed continuously from Arctic regions. At all events, there seems to be no other cause to which the distribution of the boulders can be attributed.

By such a mode of transport, the boulders would of necessity be deposited just as those of the boulder formation are found to be deposited. The distance of the site of their deposition from the locality whence they were derived, would depend upon the circumstances that deter-

mined the course of, and the distance travelled by, the ice-masses, wherein or whereon they were borne. While those circumstances would be mainly of an uniform character, they would be liable to temporary variations and to permanent, though most gradual, modification.

The principal features in the result would be the transport of the boulders from a frigid to a temperate climate, and their distribution at various distances from the rocks whence they were derived over a generally determinate route.

Some variation in the mode of their deposition would however, be occasioned. Large icebergs would necessarily remain longer unmelted than smaller ones, and hence some few of them would be carried further from the north than smaller bergs; but those of the larger size would become sooner grounded upon shallow parts of the current's route; and as only the larger ice-masses would, by reason of their greater buoyant power, be capable of bearing up the largest of the boulders, one general effect would be that the smaller boulders would be conveyed to the greatest distances, with exceptional instances of an opposite kind.

The speedy or retarded melting of the ice-masses, again, would be affected by the variations to which the seasons of the period were liable, some seasons being warmer and some colder. The deposition of the transported boulders upon the underlying surface would, from that cause also, sometimes occur nearer to the places whence they were derived than others. And it would also to some extent, be affected by variations occurring in any of the other circumstances directly or indirectly connected with it, as in the temperature as well as the ve-

locity of the current itself, and the direction pursued by any of its subordinate portions. But while there occurred some variety in the circumstances under which the icebergs with their burdens of *débris* and fragments of rock were carried from Arctic latitudes, one general effect would be produced, namely, the distribution of the boulders in larger or smaller quantity over one determinate route. Meanwhile, other oceanic operations would be in progress over the area traversed by the current. In some situations, the aqueous and other rocks of which the ocean-bed consisted would be undergoing erosion or destruction; and, on the other hand, the deposition of sediment would be occurring wherever circumstances were favourable for its settlement, and the transported *débris*, sinking to the ocean bottom as soon as the bergs which bore them were partially or altogether dissolved, would become embedded in the accumulating sediment.

It appears, then, that the distinctive features presented by those portions of the aqueous rocks to which geologists have given the appellation of "northern drift" or "boulder formation," incontestably indicate that the water which, during a former era in the world's history, covered the sites whereon rocks belonging to that formation are now found, had the character of regular and permanently established ocean currents; and further, that each of those currents continuously traversed one general route. In the case of the European deposits, the current that precipitated them travelled from Arctic to temperate latitudes, or in a south-easterly direction from the part of the globe which now forms the extreme north

of Europe. In character, though not in regard to the direction it pursued, it must have resembled the Greenland current of the present time, and beneath it, the greater part, if not the whole, of the European continent must have been submerged.

From the previous quotations it appears further, that evidences of the kind pointed out are to be met with in Canada and in the United States, as far south as the 38° north, and also in the southern hemisphere between latitude 41° and Cape Horn ; indicating that those parts of the globe were also submerged beneath the ocean in some former age, and that the water which covered them had the continuous motion of regular oceanic currents.

Proving then, as the geological evidences presented by the rocks included in the boulder group do, that such extensive portions of the earth's surface as those now constituting entire continents, were once submerged beneath great oceanic currents, the question to be considered is,—Of what course of events does that fact testify ?—By what process did those ocean-beds, over which vast bodies of water thus flowed, come to acquire the condition of dry land ?—Was that result produced by the distension and physical upheaval, either bit by bit or all at once, of extensive portions of the earth's crust ? or was it not most gradually effected, without any distension or upheaval, solely in consequence of the astronomical laws and influences which regulate and determine, as well the various motions of the globe as the general condition of the water enveloping it ?

The oceans of the world unitedly form one immense

aggregate, covering by far the largest proportion of the globe's surface. Thus, the vast expanse of the north and south Pacific is united in southern latitudes, with that other expanse which comprises the Atlantic, the Southern, and the Indian oceans.

On the other hand, the principal parts of the earth's surface, which constitute the continents of the world, stand out above the water in nearly detached sections. North and South America, for instance, are united only by the narrow Isthmus of Panama; Africa is separated from Europe and Asia by the Red Sea and the Mediterranean; and although Europe is completely united to the vast Asian continent, yet it is very much broken up on its north-western coast. Australia is entirely surrounded by water; and the remaining unsubmerged parts of the globe consist of innumerable islands of larger or smaller dimensions.

On reference to an ordinary terrestrial globe, or to a map of the world, it is seen at a glance how much greater is the part of the earth's surface which is covered with water than that which constitutes the dry land; and the irresistibly encroaching power of the water, as exercised upon sea shores, is shown in the great irregularity of outline of every continent and island, and in the numberless inlets of every kind by which all coasts are marked.

Now, the idea which seems to suggest itself on such a survey being taken is, that the general condition of this vast oceanic aggregate must be determined and regulated, not by those projections upon the globe which rise above the sea-surface in the shape of continents and islands, but *by some* general laws and influences, such as those which

regulate and determine the motions of the globe itself; and that the condition of the dry land, indeed the very existence of the dry land, is chiefly dependent upon some specialty in the circumstances which determine the condition of the earth's oceanic covering. This view seems to be of greater importance when it is borne in mind that in every part of the known world the dry land presents unquestionable evidence of its having emerged above the water. The suggestion also forces itself upon one's attention, that the wearing away of some of the present dry land, which is manifestly occurring on numberless sea coasts, is an operation that is gradual, regular, and ever progressive, and one in which the water surrounding the globe is the principal agent.

Do any of the well-known explanations of astronomical science uphold and confirm these suggestions?

It is a palpable and manifest fact, that the great body of water constituting the oceans of the world is actually and conspicuously affected by the sun and moon, or by the gravitating power exercised by them, in such a way that it has a greater depth in some parts than in others. Astronomical explanations of the tidal phenomena show incontestibly that such is the case; and, also, that those deepest parts of the globe's watery covering hold positions which, as referred to certain parts of the surrounding heavens, are not altered by the diurnal rotation of the earth on its axis, nor by any other motion of the earth. From those explanations it seems to be absolutely demonstrable that, to the extent that the earth's attractive power over the ocean is overcome by the action of the sun

and moon, the water upon the globe is maintained in a condition which is independent of the earth itself; and that those, its deepest parts, are permanently maintained, notwithstanding the motions of the globe, in situations that are near to where the imaginary fixed plane of the ecliptic intersects the globe; so that, although the earth's diurnal rotation is always causing every sea-shore and sea-channel, and, in fact, every part of the solid earth's surface, to be in a state of approach towards, or of departure from, that plane, yet the situations of those deepest parts of the ocean, with reference to the surrounding heavens, is not thereby altered.

The extent to which the water surrounding the globe is thus influenced by the sun and moon is not now under discussion; it is only the fact that it is affected in the manner pointed out that is here commented upon. As shown in the tidal phenomena, it is manifest that when any particular sea-coast acquires, by means of the earth's diurnal rotation, a certain situation relatively with that part of the surrounding heavens through which the fixed plane of the ecliptic passes, a certain increased or diminished depth of water, as the case may be, is observable upon that coast. In short, the depth of water upon any sea-coast chiefly depends upon the situation the coast may happen to be in relatively with that plane.

Now, if the water upon the globe is always maintained in such a condition of unequal depth, then one of the effects resulting from that state of things would seem to be the permanent establishment of certain oceanic currents. An endeavour has been made in another portion of the

present volume to show that, in consequence of the force or power of the earth's gravitation, as exercised upon the water, being in some measure overcome by the attractive power of the sun and moon, and in consequence of the earth's force or power of gravitation not being the same in degree at all parts of the earth's surface, the two influences must be in continual contest; for the globe's rotation upon its axis is always bringing a different amount of terrestrial attractive power into contact with an unchanging amount of solar and lunar attractive power. But, inasmuch as the daily rotation of the globe is an ever recurring event, the very same course of operations is repeated in the same order each day. From these circumstances it would seem necessarily to result that a regular motion must become imparted to various parts of the ocean; in other words, that established oceanic currents must be thereby produced.

But though the principal ocean currents, like the daily tidal phenomena, are thus attributable to an astronomical origin, yet they are probably affected in a subordinate degree, by the parts of the earth's surface that stand out above the ocean as continents and islands, and which divide them into separate branches of greater or less magnitude, and which, perhaps, in some measure, deflect them from what would be their general direction but for those obstructions. While, in some parts of the world, the ocean is most gradually, though irresistibly, attacking and destroying, or overwhelming, the dry land with an increasing force, in other parts its power is as gradually diminishing, and in those regions it is, no doubt, much

influenced by the dry land in regard to the direction and velocity of its currents.

Now, if the general condition of the great oceanic collection of water that surrounds the globe is determined and regulated by the astronomical influences which govern the motions of the earth itself;—if there result from the constant exercise of those influences, not only the small daily tidal alternations, and the principal ocean currents, but also those vastly greater and deeper tidal effects, which are so gradual in their progress that many thousands of years are required for their full development;—then, the phenomena presented by the boulder formation are readily explicable. The parts of the globe's surface over which the boulder deposits are now traceable, were once the ocean bottom. By means of a most slow, but an ever progressive alteration in the direction of the earth's diurnal rotation, they were gradually brought towards positions relatively with the surrounding heavens, whence, as regards its power over the water on the globe, the solar and lunar influence is exercised in its least degree; and there consequently ensued a gradual lessening of the depth of the water which covered them. Slowly, but ever progressively, the same course of events was continued until the ocean bed began to emerge above the water, and, continuing to emerge, ultimately acquired the dimensions of a continent of dry land.

It is to be borne in mind that, though the astronomical explanations of the daily tides show *how* the water surrounding the earth is affected by the sun and moon, it is

only the *least degree* of the solar and lunar influence as thus exercised which those phenomena exhibit. It is to the diurnal rotation of the globe on its axis, in connection with solar and lunar attractive power, that the daily tides are referrible; but it is to a part of the globe's complicated motions other than that which consists of its diurnal rotation, that the great alterations in the relative levels of the land and sea surfaces are due. In neither case does the effect consist of a wave-flow of the water from one part of the world to another, though it is the same as if it did thus arise. In fact, it consists in both cases of an alteration of position, which all parts of the globe's surface are made to undergo relatively with the situation of the two luminaries by whose influence the condition of the ocean is determined and regulated. Evidently the earth's daily rotation on its axis is every moment, throughout each day, bringing every place upon the globe into a position relatively with the sun and moon different from that in which it was the moment before. But this each day's alteration of position is of every-day recurrence, exactly in the same order, excepting as it is affected by the very gradual alteration in the direction of the earth's diurnal rotation, from which there ensue those greater effects that are equivalent to a transference of water, in the course of long periods, from some parts of the globe's surface to others.

That result, produced as there is abundant reason to believe it is, by the general astronomical laws and influences which sustain the planetary system, and that govern the motions of the earth and maintain and regu-

late the condition of its encircling waters, seems to be in perfect analogy with such of the other operations of nature as we can trace and analyse. It is a link in the chain of evidence, which connects geological phenomena with astronomical causation; and it is one of numberless illustrations of the grandeur, and yet the simplicity, of those wonderful primary laws, from the constant exercise of which so many beneficent, and yet such apparently complicated effects are being continually evolved.

THE WEALDS OF KENT, SURREY, AND SUSSEX.

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(1) *The general character and the geological structure of the Wealden area and its boundaries.*—The part of our country in which the "wealds" of Kent, Surrey, and Sussex are situate affords subject-matter for much interesting consideration and inquiry. The varied picturesqueness of its scenery is well known to nature-loving Englishmen. Its agricultural fertility is remarkable. Its history is interwoven with that of the entire nation, and can in part be traced in actually extant records of one kind or another, through a considerable proportion of the time during which the human race itself has existed upon the earth. And while its geological features are so distinctive, that they have been adopted as the standard or type to which all other groups of fossiliferous strata having similar characteristics are referrible, they are also of so interesting a nature that they seem to have formed the subject of at least as much inquiry and speculation as those of any district to which geologists have directed their attention.

This typical formation, called the "Wealden," comprises a large area, which has extensive ranges of chalk hills

or downs for its northern, southern, and western boundaries, while its eastern limit extends from Folkestone on the north to Beachy Head on the south.

The hills of which its northern and southern boundaries consist, so well known as the North and South Downs, are limbs or continuous portions of the great tract of chalk which forms a considerable part of Hampshire, and is extended into the counties of Dorset, Wilts, and Somerset.

These hills are very irregular in regard to height and general configuration. Some of them are of a considerable elevation, and in some districts their descent into the enclosed area is steep, precipitous, and cliff-like; while in others, it is more or less gently sloping and undulating. Laterally they are marked by indentations of various kinds and dimensions, some of which are semicircular, others being half-oval shaped, others again being formed between tapering spurs or limbs of considerable length, which branch out from what appears to be the main body of the elevated downs; and elsewhere huge hills of chalk, having superficial areas of great extent, stand out entirely detached, though not situate at a great distance from the principal range.

While the southern side of the northern range follows a line running a little to the north of Farnham in Surrey, by Guildford and Box Hill, and northward of Reigate in Surrey, and northward of Offham and Maidstone, in Kent, and so on to Folkestone; the northern side of the southern range extends from near Petersfield in Hampshire, passes south of Midhurst in Sussex, and proceeds by Steyning

and Lewes to Eastbourne. On the western boundary of the Wealden the declivities of the chalk pursue a route which begins near Farnham, and is continued to Alton and thence onward to the neighbourhood of Petersfield.

Thus is the district under consideration enclosed on three of its sides by ranges of hills composed entirely of chalk. The included area known as the "Weald Valley" does not, however, consist of that material, for it is made up partly of clay, and partly or chiefly of sand and sandstones of various kinds and of different degrees of hardness.

In strictness, it should be added that between the sides of those chalk hills and the district occupied by the geological formation to which the name of Wealden has been technically assigned, there lies a surrounding band of soil two or three miles in width, consisting of the upper greensand, the gault, and the lower greensands, all of which are said to "crop out" in that band from beneath the chalk. As, however, it is asserted to be of marine origin, and is thus distinguished from the "Wealden" rocks, which have been deposited by fresh or brackish water, that small and alleged intermediate group does not here demand consideration.

Containing a great number of elevations of different forms and dimensions, some of which are high and extensive lines or chains of hills, this Wealden district has a superficial configuration of a most varied and interesting kind. Its soil for the most part is extremely fertile; and including, as it does, numerous elevated heath-lands and thickly wooded districts, with plantations of many kinds of

trees, there are to be seen within it landscapes of as picturesque a description as almost any that are to be met with anywhere in England.

The nature of the component materials of which the Wealden rocks consist may be seen in numerous places where sections of their elevated parts are exposed to view, as at Tunbridge, and in the cuttings of the several lines of railway by which it is traversed, and especially along the coast from the neighbourhood of Bulverhithe onwards by Hastings to Fairlight, and along the old sea-cliffs which extend, with many interruptions or indentations in their outline, from a spot called Cliff-end, near the last-mentioned place, to Winchelsea and Rye, forming in the latter part of that route the landward boundary of the Pett Level, and then marking the limits of the still larger area called Romney Marsh, as they recede more and more from the present sea margin in the direction of the ancient port, but now far inland little town of Appledore.

The cliffs which have been mentioned as extending from Bulverhithe. towards Appledore are, in fact, the terminal sections of numerous hill-ranges of various altitudes which traverse the country to a considerable distance inland, other similar hill-ranges being also distributed over the entire district of the three Wealds.

The highest vertical sections of the proper Wealden group of rocks, are exhibited about midway between the eastern extremities of the North and South Downs, namely, in the cliffs near Hastings, which rise to a height of nearly 600 feet above the sea margin at their base; and it is also at about midway between those two ranges

of chalk hills that the most elevated parts of the Wealden area occur throughout its entire length.

(2) *The causes to which the geological characteristics of the Wealden are usually attributed.*—Of course all who have studied and written upon the subject agree in the conclusion, that the rocks of which the Wealden area and the chalk hills bounding it, and indeed the whole of the surrounding country consist, were deposited by water in the form of sediment. The character of the particles composing them, their stratified structure, and their fossiliferous contents, leave no possible room for doubting, that they thus originated, and therefore, that the sites where those and the neighbouring formations now exist, were at some time or other entirely submerged beneath the water.

While the fossils of the chalk downs lying on the northern, southern, and western sides of the Weald Valley prove conclusively that the sediment composing it was deposited upon a sea or ocean bed, it appears to have been indisputably ascertained, by means of the fossil contents of the Wealden rocks, that the sedimentary matter of which they are constituted is *not* of marine origin, but was deposited by fresh or brackish water; and it is supposed that the site of its deposition was either an estuary, or the *debouchure* of a great river, while the other part of the cretaceous series, members of which lie on every side of the Wealden group, excepting its seaward boundary, was formed at the bottom of an open sea of considerable depth.

Concerning the operations whereby the geological character of the district under review was occasioned, the

following is, in effect, the explanation which seems to be generally concurred in among geologists of the present day.

It appears to have been concluded that violent subterranean forces have been and still are in operation beneath the earth's "crust" in various parts of the world, in such a way that some localities are thereby elevated to a higher level than that they previously occupied relatively with the sea-surface in their neighbourhood, while a contrary effect has been produced upon others, which have become sunken or depressed to a lower position, some having been thereby entirely submerged. The same theory also includes the supposition that many localities, districts, and regions have been subjected, alternately, both to upheaval and to depression and submergence.

While the aqueous origin of the chalk hills partly surrounding the Wealden deposits is unmistakably shown in their stratification and fossil contents, there are other circumstances which almost as plainly indicate that, at some time subsequent to the deposition of the sediment composing them, they were subjected to the eroding or destructive action of water. In their upper portions they have just the smoothness of surface and roundness of outline that a current continually flowing over them in one general direction may be supposed to have effected. The formation of the precipitous cliffs they exhibit seems to admit of no other explanation than that that part of their characteristics was produced in consequence of the hill-sides having been worn away by the wash and play of the waves, which exercised an eroding power greater in some

places than others. And the hills are also marked by more or less sloping inlets or indentations of different sorts and of various dimensions, which appear to have been excavated by the long continued flow and reflow of a large body of water at those particular places. In fact, the outline of those hills presents all the diversities that are being actually wrought upon the chalk cliffs of the sea-coasts of our own times, allowance being made for such smoothings and modifications of contour as have been effected by long continued pluvial and other atmospheric agencies.

There seems, moreover, to be little or no doubt, not only that the chalk forming the hills described was deposited by water, and thus subsequently acted upon, but that the same material was once spread over the entire district continuously with its present boundaries; and hence, that it was subsequently completely removed from the area lying within those boundaries.

The tract from which the chalk was thus removed has acquired, among geologists, the designation of the "Valley of the Weald."

To account for the presence of the Wealden rocks, in the condition in which they now exist in that valley, it is imagined that, in some remote age, its area, and that of the whole of the neighbouring district, lay submerged beneath a lake or estuary of fresh or brackish water, or, at all events, that the area upon which those rocks repose was covered by an accumulation of fresh or brackish water. The whole of the district then sunk or became collapsed, in consequence of operations of some kind which were effected by volcanic agency beneath the earth's crust.

Thereupon the sea took possession of the district, and the deposition of the marine sediment of which the chalk is constituted ensued upon a scale of great magnitude. Subsequently, however, the subterranean volcanic forces were revived beneath the region on which this vast accumulation of chalky sediment had settled, and that region was thereby raised to a higher level. During the process of upheaval, the chalk was subjected to the eroding and abrading action of the water in various ways.

At some time, but when, relatively with the upheaval of the chalk, it does not appear to have been conjectured, volcanic convulsions occurred beneath the part of the country which now forms the Weald Valley, the consequence being the further upheaval of that area, and its exposure to the action of the water in such a way that it became entirely denuded of the chalk, and so that the fresh-water sediment which had been formed in an age long anterior to that in which the deposition of the chalk took place, was thrust up to an altitude equalling, in some parts, that of the neighbouring chalk hills.

It is supposed that the most vigorous degree of that volcanic energy was exercised in a line running nearly centrally through the length of the valley; that is, beneath the portion of it which now constitutes the "Forest Ridge."

Ultimately, the whole of the region, including the Valley of the Weald and the surrounding country became upraised, by similar means, to its present altitude above the neighbouring sea.

(3) *Objections to which the current explanations respecting the origin of the Wealden rocks seem liable.*— Of course, it is not here denied that the ranges of hills and downs which form the northern, southern, and western boundaries of the Weald Valley are composed of sediment that was deposited by the sea, and that the sediment of which the Wealden rocks consist is not of marine origin.

And there can be no mistake about the fact, that the present level of the sea, in the neighbourhood of the southern and other parts of the English coast, is far below the surface of the counties of Kent and Sussex, and of course of our country generally.

Furthermore, the lines and ridges of hills lying within the Wealden Valley—those of which the fresh-water Wealden rocks are formed—are of considerable altitude, some of them having an elevation equal to, if not exceeding, that of the chalk hills and downs which bound the valley itself.

Now, to have brought about such a result, it seems inconceivable that the subterranean volcanic forces could have been exercised with perfect equability beneath all parts of the Valley of the Weald. The exercise of the supposed volcanic agency must unquestionably have differed in degree, and have happened at different times: for, first, it is supposed to have depressed the bed of the lake or estuary whereon the fresh or brackish water sediment had been previously deposited; then, for the chalk to have been removed from the district now represented by the Weald Valley, that district must have

been upraised to a much greater extent than that to which the regions lying on its northern, southern, and western boundaries were elevated; then, the whole region must have been thrust up to its present level; and, finally, a portion of it, namely, that over which the sea now flows, must have collapsed or become depressed, it being manifest that the cliffs of the entire south coast are only the vertical sections of hill-ranges which were at some time prolonged to a considerable distance seaward.

For the subterranean volcanic forces to have an upheaving effect upon the earth's enormously thick and inelastic "crust," (if indeed the globe is so formed as to have an enclosing shell or "crust,") it seems impossible to conceive otherwise than that they would operate spasmodically and in sudden convulsions of greater or less intensity. What is known historically of violent earthquakes leaves no room for doubting, that when those forces exercise their power they do so very indiscriminately. The buildings of a city, albeit of ever so substantial and massive a kind, stand but a sorry chance when visited by the calamity of earthquake. And when it is borne in mind that the entire nethermost portion of the earth's "crust," so far as it is known, is formed of the most hard, dense, and compact description of rock, having a thickness of thousands upon thousands of feet, it seems impossible to suppose that an extensive area could be elevated many hundreds of feet by this subterranean volcanic agency, without the internal and structural condition of the superincumbent rocks being thrown into a state of utter confusion.

And, in fact, it forms part of the currently accepted geological hypothesis, concerning the means whereby the Wealden rocks attained their present position above the sea level, that the subterranean volcanic forces which upraised them did operate spasmodically; that it was to a series of sudden convulsive catastrophes that the district was subjected, whereby the chalk which formerly overlaid the Weald Valley, and reposed upon an anterior fresh-water formation, became exposed to the ravages of a sweeping current until it was entirely removed; and that to the same catastrophe is due the present condition of the entire region, comprising not only that valley itself, but the chalk hills which bound it on three of its sides, and the district which has been submerged beneath and is now overflowed by the neighbouring sea.

Now, let the existing state of the Wealden rocks themselves be considered in connection with such supposed irresistibly powerful spasmodic operations. The innumerable laminæ and strata of which those rocks are mainly composed do not show any signs whatever of disturbance *inter se*. They are formed partly of loose sand, partly of thin plates which break more readily than the thinnest biscuit, (some containing between them, in a perfectly undisturbed state, myriads of one or two kinds of small fossil shells,) partly of large masses of easily crumbled sandstone, and partly of slabs or layers of bluish grey stone, which, although more compact and much harder than the others, is, in fact, also composed of laminæ and plates, and sometimes contains numerous mussel and

a few other easily-broken shells in a fossil form. These sands and sandstones present every appearance of being exactly in the same condition, so far as regards their super-position one upon the other, as that in which they were deposited by the water. In short, their *tout-ensemble* precludes even the shadow of a conjecture that any violent upraising force has been applied to them since they were deposited in the form of sediment upon the site they now occupy.

The evidence afforded by the actual condition of the Wealden rocks, and especially that portion of them which comprises the Hastings sands and sandstones, and has (according to Dr. Fitton) a thickness of at least 400 feet, seems to render utterly untenable the current hypothesis as to the alterations in the relative levels of land and sea having been occasioned by any physical upheaval of the earth's crust.

That alterations in the relative positions of the land and sea surfaces have taken place and are still occurring, in many parts of the world, there everywhere exist the most unmistakable indications. That the Weald district has become elevated above the neighbouring sea is not only plainly ascertainable on the most cursory examination of its surface and structure, but there are historical documents in existence which show, in relation to several Sussex and Kentish coast towns, that even within the last decade of centuries the sea stood at a higher level upon the shores of those counties than it now does. The contour of the entire range of coast from Beachy Head to Folkestone seems to demonstrate with clearness that the

sea level has been thus altered, and not merely that the line of the sea margin has receded—an effect that might result from an alteration in the outline of a distant part of the coast; in the encroachments of the sea, for instance, upon the cliffs of Beachy Head on the one hand, or of Folkestone and Dover, on the other. Incidental probability also points to the same conclusion, for it is hardly likely that a military stronghold, like that of Pevensey Castle for example, the basement of whose ancient remains is certainly considerably above the present high-water level, should have been erected on the accessible site it occupies, unless at the time of its erection it was protected on its seaward side by the sea itself.

Yet, while the sea level upon the Kent and Sussex coasts has been gradually becoming altered within these recent historic times, the undisturbed levelness of many square miles of coast country between Beachy Head and onwards towards Bulverhithe, and between the Fairlight cliffs and those of Folkestone, indicates plainly enough that no convulsive upheaving catastrophes have occurred since the sea thus receded.

And general probability also tells against the supposition, that such changes of level are occasioned in any way in consequence of the physical upheaval of the earth's crust, by means of subterranean volcanic agency. It appears unlikely that the heat of the interior of the earth should remain undiminished after having performed, during some former era which may properly be termed "volcanic," so grand a part towards the present settled condition of our globe, as the numberless extinct volcanoes

in various parts of the world (besides the evidence afforded by the textural character of the igneous rocks themselves) testify that it has done. The earthquakes of greater or less severity which sometimes occur, seem to indicate that, when the remaining volcanic agency does acquire activity by the ignition of confined gases or otherwise, it is with an instantaneous suddenness that it does so, and not with the placidity and calmness which must be its characteristic, if the modern "changes of level," occurring as they do in so gradual and unfelt a mode, can be properly attributed to it.

Such a process, moreover, ill accords with the established order of things displayed in every department of nature known to us; for, although important changes are ever in progress, as for instance in the climates of different parts of the world, yet occurring slowly, and only becoming conspicuous in the course of very lengthened periods, as they do, they inflict no injury upon the life with which the world teems. They seem to have been ordained all-wisely and all-beneficently, and in the exercise of a foreknowledge of the circumstances to which they require to be adapted, very different from that which must be inferred from those "changes of level," if the earth's crust is anywhere and at any time liable to fickle, indiscriminate, and destructive upheaval and dislocation.

(4) *As to the means by which the dry land has acquired its present conformation.*—If, then, the supposition of violent volcanic agency having been in operation beneath the vast accumulations of sediment, which comprise the fresh-water rocks of the Wealden group, and the chalk

and other marine formations in its neighbourhood, is untenable, is there any positive evidence, or are there any circumstances, from which a reasonable conclusion may be deduced, respecting any other means whereby the level of the sea in the neighbourhood of the English coasts became altered, and the Valley of the Weald was excavated and denuded of the chalk which covered it, and whereby the accumulation in that valley, of the materials composing the Wealden rocks took place, exactly in the order in which they are now found to be collected and compacted together?

An affirmative answer to that question seems to present itself. For, in the first place, it appears to be demonstrable, from explanations which astronomy affords us, that a most slow and gradual alteration in the relative levels of the land and sea surfaces must take place without the intervention of any physical "upheaval" of the earth's "crust," and without its being necessarily supposable that there occurs any diminution in the quantity of water of which the oceans of the world consist; and, secondly, the dry land generally (and therefore, of course, the entire Weald district, including the chalk which encompasses it on three of its sides) indicates, by its superficial and structural configuration, that the water beneath which it was once submerged became most gradually reduced in depth, and that from its slow subsidence there has resulted the present difference of level between the land and sea surfaces.

It is only the second part of the subject that will be discussed, the astronomical circumstances bearing upon it having been dealt with elsewhere in the present volume.

And, in order to ascertain in what particulars the configuration of the dry land attests that its characteristics are due to its slow emersion above the water, otherwise than by any physical dilation or upheaval of the earth's crust, (or to an effect that was equivalent to a slow subsidence of the water,) it seems necessary to consider, 1st, some of the operations that are probably in progress at the bottom of the seas and oceans of the present day; and, 2nd, the effects produced upon any region or district by reason of such its slow and gradual emersion.

Sub-oceanic operations.—The open seas and oceans of the world are branched or divided into numerous well-known currents, some of which are of enormous extent. Each of them constantly flows in one general direction, though subject to some degree of seasonal or periodical variation, which is not well understood. Probably, also, all are liable to a permanent, though most gradually effected, alteration in regard to direction and velocity. It seems to be thought that they are occasioned by the action of the trade and other winds upon the surface of the water, and partly by the difference of the water's temperature in different parts of the world; but it has been suggested in another portion of the present volume, that they are due to causes of a more general character. However that may be, it is certain that none of those ocean currents are maintained in one uniform condition throughout their length, breadth, and depth. Regarding any one of them separately, it may be said, (as, indeed, it may be said of any moving body of water,) that while as an entire mass it travels in one general

direction, the different parts of it are more or less swift or retarded, and pursue courses that are not exactly parallel with each other. It is in consequence of the susceptibility of the watery element to motive influence generally, and of its instant readiness to be stayed or turned aside by immovable or sufficiently unyielding impediments, that a great degree of variableness and inequability of velocity and direction thus characterises the subordinate parts of every stream.

There is no doubt that the depth of the sea in some places is very different from its depth in others, and that the ocean bottom is marked by the various kinds of superficial irregularity which are to be met with upon the dry land. The continents and islands of the world rise from the ocean bed with every variety of contour, and it is impossible to conceive otherwise than that the submerged portions of the earth's surface consist of elevations of every variety of height, dimension, and form, and of every degree of steepness.

While the general condition of the water surrounding our globe may be considered as so far permanent that it is only liable to the gradually progressive change which astronomical influences may produce upon it, it may at the same time be reasonably concluded that by means of the water, the submerged parts of the earth's surface are continually undergoing alteration as regards its configuration. While some parts of the ocean depths are characterized by a placid stillness, by reason of the protection against the ravages of currents afforded by hill and mountain ranges, in other parts the ocean bed

is being subjected to the eroding and destructive action of currents. Hence it is more than likely that the sediment produced from the wearing away of some parts of the ocean bottom is transported to other localities where stillness prevails and where circumstances are favourable for its deposition. And it is probably distributed with approximate equability over the district to which it is borne; the results being these,—that where a plain or level previously existed, there the sediment will accumulate in nearly horizontal strata, and the character of a level or plain will be preserved; where the deposition takes place over an undulating or hilly locality, there an undulating or a hilly configuration will be maintained with more or less modification; and where the ocean bottom is rugged and precipitous, there the sediment will have a tendency partly to fill up the most angular portions of the irregularities of the locality, and ultimately to accumulate in the form of steeply sloping hills.

That such a mode of deposition occurs we are justified in believing, from the condition in which the marine sedimentary rocks now above the sea level are found to be. That the materials composing them were deposited thus equably, and that the strata of which they are constituted now hold exactly the position of horizontality, or of divergence from horizontality, in which they were originally formed, seems to be plainly manifested by the absolutely undisturbed state as well of the strata themselves as of the laminæ and particles of which each stratum is composed. And that many of those rocks,—the chalk and London clay, for instance,—were accumu-

lated at the bottom of seas of greater or less depth is, by all geologists, said to be unmistakably attested by the character of the fossils embedded in them.

Under these circumstances it cannot but happen that the sea and ocean bottoms have a configuration of a very varied character. In some parts, prior accumulations of sediment, which had been deposited in protected situations, probably become, in the course of time, liable to erosion, in consequence of portions of the great ocean currents acquiring a changed direction, and of a motion being thereby imparted to some of the deeper parts of the ocean which were previously quiescent. In other parts, prior deposits may become entirely removed by the operation of those currents, and the primitive and others of the hardest descriptions of rock may thereby be left in a denuded state. Elsewhere, the sediment probably accumulates in the form of plains, mounds, hills, and hill-ranges of different forms and dimensions. But while all this change is going on, and this variety of contour is the result, the general effects are most likely of an approximately uniform character. A current which ever flows on in one general direction cannot produce, either by the deposition of the sediment it transports from place to place, or by its abrading action, hills, or lines of hills, or valley excavations, in such a manner that those elevations and valleys should, lengthwise, be transverse to the route along or over which it travels. By reason, however, of its various parts flowing in directions which are not absolutely parallel with each other, the direction of the various lines of elevations and valleys which are formed probably diverges from paral-

lelism in a greater or less degree, just as we find the various hills and valleys of the dry land to do.

That such effects are produced upon the bottom of sea and ocean is to be inferred from a consideration of the nature of large moving bodies of water, and of the extreme susceptibility of that element to the influence of gravitation. And it is of effects of that character that the features everywhere presented by the dry land itself seem to testify. In most mountain regions, the highest peaks and ridges and the most precipitous valleys, appear to have been denuded of the sediment which once covered them, and the primitive and other hardest descriptions of rock are comparatively bare of soil. It is, for the most part, in situations that are not of the greatest altitude that aqueous rocks are situate; and their structure and general conformation seem manifestly to indicate that they originated under, or have been affected by circumstances of the nature here pointed out. All the highest lines of hill in every district lie in the same *general* direction— that is, although relatively with each other they are not absolutely parallel, yet they are never transverse. The intermediate hills of lesser height are less regular in that respect, but they, too, preserve a general uniformity of direction. Many main hill-ranges, and sometimes lower ones also, are abruptly terminated, as if long after their formation they had been assailed by a current which had gradually changed its direction to one somewhat transverse to their position, resulting in the bluffs or headlands now existing, and which are very similar in appearance to the bluffs and headlands of present sea-shores. The appearance of the lower eminences of every

district seems to indicate that they also have been operated upon by currents which had gradually changed their course. Such of the hills as are composed of a comparatively hard substance, as the chalk, are all more or less worn or eroded. Escarpments and cliffs of various degrees of steepness, inlets and bays of numerous forms and of all the variety of outline which distinguishes the sea-coasts of our own times, may be traced among them. Some valleys seem to exist at the present time just as they were originally formed by the accumulation of the sediment on the ocean bed into the hills by which those valleys are bounded. Other valleys appear to be more or less due to the excavating operation of currents. The hill-sides along every river's course are marked by terraces and cliffs, and, in short, the configuration of every district seems to indicate most plainly that it has been only and entirely effected by means of water.

As to the effects produced upon any submerged region through its slow emersion above the sea.—Now, supposing the submerged portions of the earth's surface to be thus operated upon by the water surrounding our globe, and that by means of certain astronomical laws or influences which are in constant exercise, certain regions are made to emerge most gradually above the sea surface, what would be the effects produced upon any region in consequence of that process of emersion? As the region or district approached towards the sea surface, it would become exposed to the action of the upper currents of the water, and the manner in which it would become affected thereby would, in a great measure, depend upon the configuration of the district itself. Some localities would be protected by high

mountain and hill-ranges, and would be subjected to no eroding operations; others, however, would be partially exposed to them; and others, again, such as the highest peaks and ridges of mountains and hills, being accessible to the full power of the currents, would have their granitic or other indestructible substructure more or less denuded of its sedimentary covering.

As soon as any portion of the district permanently attained a position above the sea-level, the rain would descend upon it, and as it more and more emerged, fresh water would be collected into its valleys, and would, through them, find its way to the sea. In its seaward journey the fresh water would become pent up in many places in the form of lakes, and while it would excavate channels for itself in the valley beds, fresh-water sediment would become formed by its means, and be transported to and deposited in localities at various parts of a river's course, wherever there existed facilities for its accumulation.

As the same region attained a still greater elevation above the sea, and as its emerging area increased, the facilities for its drainage would become increased, and river channels would become deepened; some of the lakes formed in its highest mountain valleys would become drained, leaving river channels in their beds; sea-shores would be subject to the action of the sea waves, and to the set of the sea currents, and sea cliffs would be formed, and an irregularity of coast outline would be the result.

Before the emersion of the region, valleys lying between hills of marine sediment would become liable to the erosive action of the upper sea currents; or if, prior to

or during its emergence they were protected from such an operation, then, when they came to form part of the dry land, and to be the channels for the outflow of the land drainage, they would become eroded and worn by fresh-water streams.

The continued emergence of a district above the sea must, of necessity, affect its general condition; the effect being the same as if the sea level around the shores of the district were actually lowered. Any valley that debouched upon the sea and continued during a long period to be occupied by salt water only, and to be exposed to the continual advance and recession of the tides, would gradually become occupied by the outflowing currents of fresh water. The further rising of the land must cause the fresh-water currents traversing its valleys to flow more rapidly seaward, to deepen their channels, and otherwise, by their erosive action, to act upon the contour of the valleys themselves. The general effect of such a course of events upon a district must be the same as if a gradual subsidence of the sea in its neighbourhood were occurring. The fresh water stored up in lakes and inland seas would become gradually and permanently reduced—a result necessarily following a lowering of the sea level. Upon the beds of those lakes and inland seas, formed originally in depressions existing amidst vast accumulations of marine sediment, the deposition of fresh-water sediment must ensue on a scale of great magnitude. The same description of sediment must also become deposited in various parts of the route of every fresh-water river; and hence, in the valleys formed between hills consisting of marine sediment, fresh-water sediment would become deposited in the form of elongated hills of

larger or smaller dimensions. By a further reduction in those fresh-water collections, which must necessarily ensue upon a lowering of the sea level, the outline of some of those accumulations of fresh-water sediment would itself become subject to alteration in various ways, and sometimes they would suffer total destruction.

For the purpose of estimating, in some measure, the effects that a gradual retreat of the ocean is calculated to produce upon the superficial contour of the land from which it recedes, a very simple and familiar illustration may be resorted to.

Most sojourners at the sea-side must have noticed that small accumulations of water are left by every retreating tide in depressions of various kinds, which are formed upon the shore by the action of the sea in many places between high and low-water mark. They generally occur upon gently sloping shores where there is a considerable depth of sand, the completely saturated condition of which prevents the water in these "tide-pools" from percolating through it. They are occasioned sometimes in consequence of fragments of chalk or stone being strewed upon the shore, and of the water being made to play around them with some violence by the advance and recession of the waves, and sometimes by reason of the sand being heaped up into banks upon the upper parts of the shore in such a manner as to cause the water to be retained behind those banks as the tide recedes. At all events, many such pools may be seen during the time of ebb upon every shallow strand, and the effects produced by the gradual discharge of their contents, after the receding tide has ceased to keep them filled, seem

to be very similar on a comparatively microscopical scale, to those which are indicated by the superficial contour not only of the entire Wealden area particularly, but also of every other locality where aqueous rocks abound—that is to say, of the dry land generally.

In consequence of the gradual recession of the tide, the seaward part of the margin of every such pool or collection of banked-up water is longest subjected to the action of the waves, and is therefore somewhat lower than the other parts of it. Hence, it is through or over that part of the margin of the depression that the water behind it begins to force its way, shortly after the waves have ceased to pass over it, thereby making for itself a little channel of outflow. As the tide still further recedes, the sand in which the pool has been formed becomes more and more drained of the water which before had completely saturated it, and it is thereby rendered more susceptible to the pressure of the water in the pool, which deepens its channel of exit, while it gradually discharges itself, until it is altogether drained off.

Sometimes a depression of that kind, formed in the higher part of a sandy shore, is large enough to produce a streamlet of considerable force and velocity, which continues to flow until or after the tide has reached its lowest limit, and it is in such a case that the effects alluded to may be best observed. As long as the water of the sea reaches near to the lower margin of the pool or basin, it affords support to the part of the sand in which the pool itself is formed; but, by its gradual recession to a lower level, that support becomes more and more diminished,

and ultimately it ceases altogether. By the continued lowering of the sea level, the character of the streamlet undergoes considerable alteration; the distance it has to traverse is increased, although its course from the pool to the sea margin is nearly direct; yet the current itself is not in the same condition in every part, for in some places it flows swiftly between steep banks in a narrow channel, which it has a tendency to deepen, in others, where it flows more slowly and is shallow, it spreads itself out over a continuously widening area, and deposits some of the sediment it brings down with it, in little elongated islets, which become more numerous as the volume of water decreases. However straight the general direction of the stream may be, the water hardly anywhere flows parallel with its banks, but sets obliquely against them at particular spots, first on one side and then on the other, and being repelled therefrom in a downward direction, at nearly the same angle as that at which it made its approach, it pursues its seaward journey in a somewhat zig-zag course, producing by its erosive action results which have any thing but a uniform character.

The effects thus produced upon a sandy sea-shore by the recession of the tide, seem very nearly to resemble some of the characteristics which the superficial configuration of the dry land presents, on a great scale, in every place where aqueous rocks are situate. As previously remarked, those characteristics seem to indicate most emphatically, that the water beneath which the present dry land was once submerged, became gradually shallower

and shallower, until the sea bed became formed into dry land, by a process of slow but ever-progressive emersion; and they also seem to show, that the great basins and depressions in the land surface, which were for a long period occupied by enormous collections of water, were gradually drained in a way exactly similar to that in which the tide-pools of sandy coasts become emptied of their contents.

(5) *The probable course of events to which the existence of the Wealden rocks is attributable.*

The following is a brief recapitulation of some of the undisputed facts that are plainly indicated by various characteristics of the Wealden district.

(1) The region in which that district is situate was, during some long period, deeply submerged beneath the ocean, that is to say, the whole of Great Britain was thus submerged.

(2) The Wealden rocks, consisting of clay, sand, and different kinds of sandstone, were deposited by fresh or brackish water; and hence, during their deposition, the site upon which they are situate must have been submerged beneath a great accumulation of fresh or brackish water; that is to say, beneath the waters of a lake, a river, or an estuary.

(3) The Weald Valley is surrounded on all sides, excepting its seaward boundary, by a great marine deposit of chalk; the lines of chalk hills known as the North

and South Downs being respectively situate on the north and south sides of the valley. Within the valley, and along the three sides of it which are bounded by the chalk, there are other deposits which are also supposed to be of marine origin. They consist of the upper greensand, the gault, and the lower greensands; they have a breadth of about two or three miles, reckoning from the chalk hills; and they comprise valleys and hills of various forms and dimensions. The highest of the hills, or rather hill-ranges, constituting this band, consist of the lower greensands, and lie, for the most part, at the greatest distance from the chalk hills; hence, they are the immediate boundaries of an inner part of the great valley. These greensand hills are so steep in many places that they almost present the appearance of escarpments or cliffs.

(4) The Wealden rocks, which at the time of their deposition, consisted of fresh or brackish water sediment, occupy the inner part of the valley. They comprise hills and hill-ranges of various forms and dimensions, some of them having an altitude equal to or greater than that of the chalk downs surrounding the Great Weald Valley.

(5) The surface of the whole region, including the elevations within the Wealden area, as well as those by which it is bounded on its northern, southern, and western sides, bears unmistakable signs of its having been operated upon by the eroding and excavating action of water.

These being some of the leading characteristics of the Wealden district, let the following propositions, which are deduced from the matters discussed elsewhere in the

present volume be regarded as true, at least for this occasion.

(1) By the instrumentality of the water which nearly surrounds the globe, great accumulations of sediment are ever taking place in some submerged regions, while in others, processes of erosion and denudation are going forward.

(2) Most gradual but ever progressive alterations have been during past ages, and still are occurring, as between some of the submerged parts of the globe's surface and the surface of the oceans covering them, so that the formation of dry land is caused by submerged regions gradually rising towards, and then emerging above and attaining an increased altitude above the sea surface; while elsewhere, the dry land is becoming slowly submerged, and already submerged districts are being as slowly brought under a greater depth of water.

To what course of events, then, consistently with the facts and deductions thus enumerated, can the existence of the Wealden rocks be attributed? The following suggestions are intended as an answer to that question.

During a very lengthened period, the marine sediment, of which the chalk is composed, accumulated over a very extensive submerged portion of the earth's surface. The accumulation took place in such a way that hills, hill-ranges, and valleys—all of various forms and dimensions—were the result.

During or subsequently to the time when the chalk of the region in which the Wealden district is situate accumulated, that part of the earth's surface was, by astrono-

mical means, approaching very gradually towards the sea surface. As gradually emerging out of the water it ultimately attained a considerable altitude above it.

Before the hills and hill-ranges now situate in the valley existed, it may have been a valley or depression naturally formed during the process of deposition in the great chalk-bed of the ocean, and have been subsequently deepened and widened by the erosive action of sea currents; or it may have been partly, or altogether, excavated by the action of a great fresh-water stream which flowed over it to the sea, when the region wherein it is situate had so emerged above the water as to form a continent; and when the valley itself became the site through which the overflow of great collections of fresh water was, in part, discharged into the sea. England was then, probably, united to the continent, and the existing channel of the Dover Straits had not been excavated to anything like its present depth.

On the valley becoming an estuary, or the site over which, or the channel through which, a large body of fresh water was thus discharged, the deposition of brackish and fresh-water sediment occurred in various parts of its bed. The previous conformation of the valley was probably of a hilly or an undulatory character, and that circumstance combined with the inherent tendency of currents to deposit the matter with which they are charged otherwise than horizontally, caused the sediment to accumulate in the form of hills and hill-ranges, whose longer axes, necessarily, were parallel, or nearly parallel, with the direction of the down-flowing stream.

As the water which thus flowed over the district was gradually shallowing, subordinate parts of it would, in virtue of gravitation, be more and more inclined to become concentrated into any minor valleys or depressions that had been formed in the most elevated parts of the surface over which the main stream travelled. And even when the surrounding region of chalk came to stand out above the water, as islands or banks, those minor channels would be still further eroded and deepened by the streams that continued to flow through them. The valleys that traverse the chalk in Kent, Surrey, and Sussex, and through which the principal rivers of those counties now find their way, present the most unmistakable signs of their having been thus operated upon. They are so marked as to show plainly that they were once wholly occupied by streams; that from that time to the present, streams have ever continued to flow through them; and that throughout the entire period those streams have most slowly become diminished in depth and volume.

While the great body of fresh water that flowed from the west or north-west, and in part poured over the district of the Weald, was becoming reduced in depth, the water filling the Weald Valley itself was more or less mingled with water from the sea. And when at length the chalk of the surrounding region was left entirely uncovered, then the valley would acquire the character of a great estuary, or of a sea inlet that was nearly land-locked. It would, of course, continue to be subject to tidal alternations, and as the land that nearly surrounded it was then of no great elevation,—for it is the Weald Valley as supposed

to be occupied by water to the depth of upwards of five hundred feet, that is under consideration,—it would be open to all the stormy influences to which great expanses of water are ever liable.

During the period in which the valley was thus occupied by water, whether its character was that of a great estuary or merely that of a land-locked inlet from the sea, the chalk elevations which formed its landward boundaries would constitute its coasts; and those coasts would be exposed to all such assaults of the waves as tempest violence can produce, and to the more insidious and not less potent attacks that result from tidal action.

The way in which chalk cliffs are undermined and demolished by the sea may be witnessed at any time on coasts of the present day. After being brought down in huge quantities, the chalk becomes broken up into large and small fragments, and then subjected to the tumultuous action of the water. The sea margin, for some distance from the shore, may be seen to be densely opaque, in consequence of the quantity of fine sedimentary matter that is suspended in it, and which is derived from the loose *débris* and partially dissolved material that is dispersed over the shallow shore beneath. There can hardly be a doubt that, wherever such operations are in progress, new sedimentary rocks are being formed out of various constituents that are thus being mingled together. Where it is chalk of which a sea-beaten coast is composed, chalk would be the principal element in the new formation; and where other substances also exist, such as shingle, sand, and comminuted shell, they too

would be mixed up with the new deposit in larger or smaller proportions.

Now, not only do the chalk hills around the Weald indicate, by the contour of that part of them which is towards the valley, that they have been subjected to aqueous action of this description, but the elevations that stand out in the front of them, at a distance of two or three miles, and that are situate within the valley and are generally parallel with them, are in the very position that would be occupied by deposits formed in the manner just described. Asserted as those deposits are, however, by the most competent authorities, to be of pre-cretaceous origin, the contrary is not intended to be here affirmed. Yet, but for the difficulty interposed by the decided character of their fossil records, their situation, the manner in which they have evidently been acted upon by water, and their constituent materials, are all suggestive of their having been deposited when the Valley of the Weald was last occupied by water from the sea, and while a gradual shallowing of that element in this part of the world was going forward. If it had happened that, in a former period, a vast marine deposit of blue clay formed the bed of the Weald Valley, extending it may be, to other regions under and beyond the surrounding deposit of chalk, then the existing condition of the Wealden area would not seem difficult to account for, supposing that there subsequently took place the events which have been described. If such a valley formed an estuary into which a great fresh-water current was discharged, the upper parts of its blue clay bed would become, more or less, dissolved

and broken up; estuary fossils would become deposited, and great accumulations of fresh or brackish water sediment would ensue. Subsequently, the great fresh-water stream that was discharged into the valley would become so greatly reduced in depth, that it was obstructed and deflected by the elevations of chalk that encompass the valley. Then the valley became almost completely occupied by water from the sea, the cliffs of its shores were undermined and broken up, and out of the materials thence derived new deposits were formed. Filled as it was to the depth of four or five hundred feet, the operations that continued in progress upon its bed and upon its shores were of no feeble description. As, however, the sea in the neighbourhood went on diminishing in depth, one range of hills after another that had been formed in the valley, both estuary deposits and those of subsequent marine origin, came to stand out above the water, which would thus, ultimately, be divided into separate branches, and the sides of those hills, and the debouchures of their lateral valleys that yet remained accessible to the water, would suffer from erosion and other aqueous agencies. Finally, the district became altogether raised above the sea level, and it was only through its deepest valleys that its waters were ultimately drained directly into the sea, by such rivers as those of which mention is made in our earliest historical records.

But the circumstances to which was due the gradual shallowing of the sea in the region in which the Weald is situate, would occasion a change in the direction, not only of principal sea currents, but also of subordinate

currents that impinged upon sea coasts. Hence, while the district of which the Weald forms a part was acquiring an increasing altitude above the water, its outer coast lines would become altered. While in some localities the coast cliffs would be demolished, in others they would attain an inland position. Accordingly, these are the very characteristics of the line of cliffs now marking the debouchure of the great Weald Valley. The inferences deducible from the existence of the ancient coast line which extends inland from Fairlight by Winchelsea and Rye, and onwards past Appledore, are coincident with those to which all the other features of the district under consideration so emphatically point.

Any one who will take the trouble of carefully inspecting the district that extends from the chalk hills behind Folkestone, to Sandgate and Hythe, can hardly fail to perceive how conspicuously the land of the neighbourhood, consisting of the lower greensands, is marked at all heights by sharp-edged cliff-like declivities. An almost continuous series of terraces and cliffs extends from beyond the depression at the base of the chalk right away to the great shingly area of Romney Marsh. That these features have been produced by the action of water there cannot be a doubt. Whether the coast road or an inland route from Folkestone to Hythe be pursued, there are, over and over again, presented to the attention of the observer the most convincing proofs that it was from aqueous operations alone that the locality acquired its present conformation. Besides the terraces and cliffs which have been mentioned, and which of themselves are plainly indicative of an effect

equivalent to the gradual subsidence of the sea, there are valleys and depressions of various kinds whose contour is manifestly referrible to the same cause. It is upon the top of the bank of a valley (evidently once a small sea inlet or a river debouchure) that the ancient castle of Saltwood is situate. The surface of the land in the immediate neighbourhood of that ancient stronghold still retains, even in spite of the levelling agency of the plough, the most unmistakable signs of its having been subjected to the various operations of gradually subsiding water. And the very situation of the castle is suggestive of a depth of water considerably greater than at present having existed in the neighbourhood, in times even more recent than is generally supposed; for it is difficult to conceive why that particular spot should have been chosen for the castle, unless the district which it immediately overlooks had been more or less covered by water, whereby the building was originally protected from attack. This view seems to derive additional weight from the fact, that situations of that kind were often selected in ancient times for the erection of such places of defence.

Cliffs and terraces like those of the district under consideration not only characterize the banks of every river and the sides of almost every valley that is now or ever has been traversed by a river—they not only have their counterparts on a scale of vastly greater magnitude in various parts of the world, as in the steppes of Russia and the elevated plateaux of Mexico—but they are illustrated by effects that may be *actually seen* to result from the action of gradually subsiding water. Thus, the shingle

upon the shore, a material which admits of being thus operated upon, is formed by the retreating tide into nearly vertical banks of a few feet high, and into nearly horizontal areas of several feet wide. The banks of natural reservoirs wherein water is stored for domestic use—such as the ponds at Highgate, for instance—have been observed to be worn into steps of smaller dimensions, when, for purposes of repair, they have been gradually drained of the water contained in them. And, to descend to a ridiculously insignificant example, it may be often noticed that the sides of little depressions which recently evaporated rain-puddles have occupied, are marked in a proportionately minute degree by superficial irregularities of exactly the same description.

Whatever, then, may be the nature of the evidence afforded by the fossil contents of the different rocks composing the cretaceous group, the contour of the Wealden Valley and of the district which surrounds it, seems certainly to indicate by its various characteristics, that it is due to one regular, and ever-progressive course of events—namely, to the gradual elevation of the globe's surface in this part of the world above the sea level by other means than the dilation or expansion of the earth's crust through volcanic or other physical upheaving agency. The features, indeed, of the part of the country which has been briefly reviewed in the preceding pages, agree with those presented by the dry land generally, in demonstrating that the very existence of dry land is due to an effect that is equivalent to a gradual subsidence of the sea in the course of very lengthened periods. And that the formation of continents

and islands should be thus produced by the slowest degrees, and without the intervention of a fitful, spasmodic, and life-endangering agency like that of subterranean volcanic force, seems only consistent with those wonderful provisions for the well-being of the earth's teeming inhabitants which are traceable in every department of nature.

THE GREAT ORME'S HEAD.

Some of the features of the headland described—The circumstances in which they originated—It is probable that the part of the world in which are the British Isles, was once in a condition similar to that of the Polynesian region of the Pacific Ocean—Concluding remarks.

It is no uneventful history that our earth has recorded of itself. Its rocks, with their fossil contents—its sea-shores—its mountains, hills, and valleys—its numberless extinct volcanoes—its ancient sea beds and river channels—its former coast lines that are now far inland—and the numberless other features of its superficial contour, present to all who engage themselves in an attempt to decipher its annals, a narrative of a most varied and interesting description.

Like the rocks of numerous other sea-coasts, those of the Great Orme's Head and its immediate neighbourhood contain a chronicle that extends over no insignificant period. They belong to a group which holds a place far down in the geological table, and whose origin is attributed to a time when the condition of the globe we inhabit was very different from what it now is. It would seem to be literally true, that since that date many a valley has been exalted, and that many a mountain and hill have been made low, while seas have been dried up and springs have been made

dry. In fact, the face of large portions of the earth has been completely changed. During different periods, races of animal organisms have lived and flourished upon the earth, and in river, lake, and sea, and have then altogether disappeared from our arena of creation. A vast development of a few gigantic kinds of vegetation seems to have been followed by productions of many sorts, that came into existence, as they were needed, for the newer forms of animate life that successively appeared upon the scene.

Very few of these matters, however, will be discussed in the pages that immediately follow, the remarks contained in which will be of a very unambitious character, and will be pri cipally confined to a brief consideration of the probable causes to which are mainly due the existing condition of that fine old headland of the Great Orme.

Formed of mountain limestone, as the Great Orme for the most part or altogether is, the internal evidence of its aqueous origin of course consists in the marine fossils contained in it, and in the stratification of its structure. Hence, the inquiry extends to the origin and elevation above the sea, of aqueous deposits generally, and, in fact, resolves itself into the question, "By what process was it that the surfaces of the sea and land have become altered in relation to each other?"

The fossil contents and the stratified structure of this massive accumulation of rocks leave no possible room for doubting that a "change of level" has taken place as between its surface and that of the water which nearly surrounds it; but while, on the one hand, there is a total absence of any other circumstance from which it can be

inferred that it was gradually, or suddenly, or in any way thrust up above the sea level by subterranean volcanic force, it presents, on the other, the most clear and positive indications of its existing condition being due to an operation that was equivalent to a gradual subsidence of the water in its neighbourhood.

In many places on all sides of the headland and at different altitudes, quarries for building and road making purposes have been formed, in all of which the stratified formation of the rocks is clearly seen. The strata thus revealed in any one place are so far perfectly uniform, that they all correspond with each other in the general direction of their "dip," some layers being, of course, thicker than others, and the thickness of each being, not the same in all parts, but thicker or thinner just according to the mode in which they were originally deposited. While such their "dip," or departure from a position of horizontality is considerable,—a characteristic indicative of an unequally applied force, supposing them to have been "upheaved,"—they are not waved, nor are they, in any manner, broken or jumbled together, as they could hardly fail to have been had they been thus elevated. In short, they present no internal signs whatever of disturbance, or of their having been subjected to an upheaving force since the time of their deposition in the form of sediment.

And while it is indicated by the "dip" characterising those rocks, that the force which raised them to their present altitude—still assuming them to have been raised—was unequal as regards the horizontality of its application, it is demonstrated, by the appearance of the cliffs on all

sides of the mountain, that their upheaval was most slow and gradual, for every part of their rugged and precipitous faces or vertical sections, from base to summit, bears a water-worn and eroded aspect, as plainly and manifestly as do the parts which are yet being operated upon by the constant action of the sea. This effect could not have been produced had their elevation happened suddenly at one time, or in paroxysms at different times. To reconcile these simple evidences with the hypothesis of "upheaval," therefore, there seems to be no alternative but to conceive that, after the whole of the sediment composing this vast mass of limestone had been deposited beneath the water, the entire mountain was raised to its present height of five or six hundred feet, either gradually and constantly during a vast period, or spasmodically and bit by bit at very distant intervals, by a subterranean force which was of enormous power, and was exercised with such absolute equability that the continuity of each stratum, and the conformity of the strata with each other, were in nowise disturbed, and so that the brittle material of which the rocks are composed should be made to show no signs of the violence to which they were subjected.

Proceeding on the assumption that the dry land has *not* been thus forcibly elevated since the aqueous rocks were formed, the following questions arise:—

(1) How came the strata to be arranged otherwise than horizontally, if they are now lying as they were deposited by the water?—for aqueous deposits they certainly are. And—

(2) What evidences are traceable in and about the

Great Orme of the sea having gradually subsided until it came to acquire its present level in relation to the neighbouring land?

A satisfactory answer to the first question immediately presents itself. When the aqueous part of the rocks began to be formed, the submerged surface on which the sediment settled was itself marked by great irregularity; and the particles, first of one sort and then of another, that were derived from previously existing rocks of different kinds, by means of the erosive action of currents, were deposited gradually and equably, or nearly equably, over the subjacent surface of the district to which they were transported, whose contour was thus approximately maintained even while the particles were accumulating into strata, and while one stratum after another was being added to the formation.

That the rocks composing the Great Orme were originally deposited by water, and that to the whole of their depth they were once completely submerged, there cannot be any doubt whatever. And that they attained their present altitude above the sea level, in consequence of the depth of the sea in the neighbourhood having been gradually reduced,—that is to say, in consequence of an effect that was equivalent to an actual subsidence of the water,—seems to be also conclusively indicated by many easily traceable signs.

The configuration of every part of the headland, including as well the various sloping and horizontal areas which occur upon it at various altitudes, as the rugged and precipitous cliffs which entirely surround it, exhibits

effects that have evidently been produced by the wearing and destructive agency of the waves of a most gradually subsiding sea. Many of those areas are separated from others by gently-sloping elevations that are terminated by perpendicular water-worn precipices. Some are encompassed by similar precipices on every side excepting their lowest, through which, probably, the water had ingress and egress when their character was that of tidal bays. There are also elevations of various dimensions that have been rounded by aqueous action into the form of hills. Upon the highest parts of these hills there is little or no soil, and portions of the nearly horizontal strata of limestone lying at or near their surface have been loosened, and have become broken up into fragments by pluvial and atmospheric agencies. By the same means, also, the forms of fossils that are embedded in many of those fragments have become very clearly defined, and numerous individual fossils, which have been similarly operated upon, lie scattered about or are partially buried in the soil, which has accumulated in some places to the depth of a few inches.

Looking from any of the higher parts of the Great Orme, and regarding the characteristics of the headland itself, with reference to the contour of the narrow and nearly level strip of land that lies between it and the chain of limestone hills which terminates in the neighbouring headland of the Little Orme, an observer can hardly fail to be convinced that the Great Orme was entirely surrounded by the sea at no very distant date.

And when the fact that the chain of lower hills alluded

to, is composed of precisely the same kind of material as that which constitutes the Great Orme, is considered in connection with the conformation of the whole district, the further suggestion naturally presents itself, that the two headlands were originally united in consequence of the same sedimentary deposit of which both are composed having also occupied the intermediate space. Supposing it happened that, subsequently to the accumulation of that deposit, but prior to its acquiring an indurated condition, a powerful current traversed the intervening area, then a channel would be excavated, and the two elevations would become separated. A stream flowing in a north-easterly or a south-westerly direction—that is, nearly in a continuous line with the Menai Straits, would probably produce such a result.

It seems likely, indeed, that the same sedimentary deposit originally extended continuously over a considerable area, for other not very distant promontories, as Colwyn on the one hand, and Dinmor Point, not far from Beaumaris, on the other, are formed of the mountain limestone of which the Great and Little Orme are composed. But the breaking up of the intervening tracts may not have occurred till the sea in this part of the world had become greatly reduced in depth, nor until it had receded from the earlier and more elevated formations of the neighbourhood—from the mountain ranges of Carnarvon and Denbigh, for instance. A gradual lessening of the depth of the sea to so great an extent as to cause those higher mountains to stand permanently out above the water, would of necessity occasion an alteration in the direction of the currents;

and as its depth became still further reduced, the water would, by the irregular configuration of the surface over which it travelled, become more and more divided into streams of smaller volume.

But not only is it indicated by the sea-beaten precipices upon the upper parts of the Great Orme, and by the bays and inlets existing in various situations upon it at different altitudes (some of which are of small size, while others are large enough for the location of entire villages), as well as by the other features already alluded to, that a slow subsidence of the sea has taken place; but the condition of the low sandy tract on which part of the rising town of Llandudno is situate seems to point to the same conclusion. That tract has just the conformation which characterises many very shallow shores whereon the water remains only during a short period in the course of each tide. Its surface is some fifteen or twenty feet above high-water level, and it forms on one side, the elevated boundary of another sandy tract which *is* covered with water during the highest part of each tide. The waters which are drained into the picturesque valley of Llanrwst, and which form the river Conway, are discharged upon the last-mentioned expanse, and in traversing it they make in it branching channels, through which they escape to the sea between the Great Orme and Penmaen Mawr. These headlands, however, are a considerable distance apart, and a large area is enclosed by the land of which on the one side and the other, respectively, they form the terminating promontories. Over that lower area, which becomes narrowed upwards towards and above the town

of Conway, the sea quietly ebbs and flows, so that a large portion of it is left quite dry during the greater part of each tide, excepting where the comparatively small outflowing body of water of which the Conway now consists, permanently maintains in its bed the branching channels already mentioned. It is, in fact, a shallow estuary, into and out of which the sea ebbs and flows so leisurely as to facilitate the deposition of sandy sediment over its entire surface, wherein numerous mussel and other shells are ever being embedded.

Now the higher sandy tract of dry land which lies between the Great and Little Orme, and one side of which forms an elevated boundary of this estuary, has just the characteristics that the lower one would present if the sea were to undergo a further subsidence and leave it always dry. Its surface has just such a departure from flatness and levelness as would have been imparted to it, if the sand or sediment of which it is composed had been deposited by a quietly flowing and reflowing body of shallow water, whose volume, velocity, and depth, were greater towards its lower or seaward parts. Some miles along the Conway estuary, above which this boundary rises, it exhibits the section of a cliff, between whose base and the present high-water margin there is a space of many yards, which is strewed with once sea-washed rock fragments and shingle, evidently the *débris* from neighbouring formations. The cliff itself rises to a height of at least fifteen or twenty feet, and was doubtless formed by the constant action of a vastly larger stream or body of water than that of which the Conway now consists, which made for itself

a channel in the bed of a sandy expanse that was submerged beneath quietly flowing and reflowing water during the highest portion of each tide, just as the constantly outflowing current of the Conway river of the present day makes its channels of exit through the bed of the existing estuary.

Among other unmistakable indications of such a former condition of things, are the beds or layers of mussel shells, which are exposed to view in some of the sectional parts of that sandy cliff at different heights, some being only a few inches below the land surface. And most strongly does the state of those beds and strata of mussels confirm the supposition that the sea has slowly subsided, and, after partially or altogether breaking up one previously existing formation after another, has by its continued gradual subsidence, and by the consequent alteration in the direction, force, and volume of its currents, facilitated the deposition of sediment in places where it before committed ravages. The existence of the shells and the nature of the soil in which they are embedded seem most positively to demonstrate, that the elevation of the places where they are now to be found, to a height of fifteen or twenty feet above the level of the highest tides of the present day, could not possibly have been caused by forcible "upheaval." They lie in absolutely undisturbed strata, and their forms are perfectly preserved, though the material composing them, individually, is so tender and brittle as to make it difficult to extract them unbroken. The soil of some of the places where they are embedded is composed of unadhesive atoms, in great proportion of

comminuted shells, and is so susceptible of even the slightest pressure, that it is impossible to imagine those layers of mussel shells would have remained in it undisturbed in a nearly horizontal position, had the site been raised by forcible means.

The features which have been thus briefly commented upon as characterising the Great Orme's Head and the district in its immediate neighbourhood, seem then to concur with the evidences furnished by every other sea-coast, and by the dry land generally, in indicating such a course of events, that parts of the earth's surface become raised above the sea level by the slowest degrees, and by means that do not consist of a violent or actual "upheaval" of the region elevated. This result agrees with the conclusions that are deducible from astronomical phenomena. By the constant operation of the primary laws that govern the motions of the earth and of the other planets, there is produced an effect which is equivalent to a most gradual recession of the ocean from some parts of the earth's surface, while it as gradually encroaches upon and submerges other parts.

If the existing conformation of the district which includes the Great Orme is attributable to such a course of events, it may reasonably be supposed, that at the time when the sediment composing it and the neighbouring headland was deposited at the bottom of the sea, the part of the world in which our own country is situate was very similar, in regard to its general condition, to the region which is now partially submerged beneath the waters of the Pacific Ocean, and from which innumerable elevations

project above the water in the form of islands. At that time, probably, the highest mountains of Switzerland stood out above the waters as the central group of a vast and widely dispersed assemblage of islands, of which the mountains of Great Britain and Ireland constituted some of the least elevated outliers. As the water gradually became shallower and shallower, numerous archipelagoes were formed. By the slowest degrees, many a group of smaller islands came to be resolved into a single island by the emergence of the most elevated parts of intermediate districts. Several of these larger islands then became merged into one, and at length, through its continued elevation above the sea, the region acquired the dimensions of a continent.

Taking one part of the period during which these events were in progress with another, the region may be said to have been subjected to an almost infinite variety of operations through the agency of sea currents; by means of tempest-tossed waves and of tidal action; and through the instrumentality of vast collections of fresh water and their outflowing volumes. And, having passed through several phases of climate as it so manifestly has, our part of the world must also have been affected in a very great degree by the various potent influences of the atmosphere.

When the nature of those operations is borne in mind, there seems to be little cause for wondering that the complicated effects which are traceable upon every part of the dry land should have been produced. Of those operations and effects the characteristics of the Great Orme's Head

and of the localities in its neighbourhood present many examples; and although they are only a few of them which have been very imperfectly described on the present occasion, yet they are suggestive of a great multitude of details connected with the past history of our globe and its occupants. In conclusion, it may be remarked, that those details include matters of an intensely interesting character, for whether the observer engages himself in studying the gradual development of animate and inanimate life upon the earth, — a development of which the fossil records of the rocks seem to testify, — or in tracing the results that are constantly emanating from the operation of primary astronomical laws, he sees something of the marvellous provisions that have been made in behoof of the world, and he seems to obtain an occasional glimpse, feeble though it is, of that vast, magnificent, and unique design in accordance with which creation appears to have been ordained.

THE ECLIPTIC AND THE EQUATOR.

I. *Introductory.*

So completely do the various departments of science seem to be mixed up with and dependent upon each other, that it appears impossible to affirm absolutely, that there is any actual line of demarcation between them. Of astronomy, for instance, it may be said, that, besides the help it derives from chemistry, mechanics, and other branches of knowledge, mathematics form so essential a part of it, that the triumphs it has achieved would not have been won but for the great mathematical skill of its followers. The title of "Mathematicians" by which the early astronomical professors were known shows how intimately the two departments were connected in ancient times. And although geology, as a distinct department of science, may be considered as not having yet reached a very advanced stage, yet it may be said to be closely allied to many branches of knowledge which have long been prosecuted with success, and have had no unimportant bearing on the industrial and commercial affairs of the world.

Seeing that the oceans of the world are manifestly affected by astronomical influences, and that the existence of the great sedimentary deposits of which the dry land is principally composed is due to oceanic agency, it seems

not unreasonable to look to astronomy for an explanation of some of the leading geological phenomena; and the fact of its being proved, by fossil evidences, that great alterations have occurred in the climates of different parts of the world during past ages, appears to give additional weight to the suggestion, that the relationship between astronomy and geology is that of cause and effect.

It is an indisputable fact to which the rocks bear witness, that the existing continents and islands of the world have been submerged beneath the sea during some former era in the world's history. The cause to which that emersion appears to be attributable forms the subject of the pages which immediately follow.

It is visibly and palpably evident, that the tidal condition of the sea upon any particular shore, at any moment, mainly depends upon the position into which, by means of the diurnal rotary motion of the globe, that shore is being brought, relatively with the part of the heavens wherein the sun and moon are situate.

Those daily tidal phenomena, in fact, consist of a very limited alteration in the relative levels of the land and sea surfaces; an alteration that is ever recurringly fluctuating between a minimum and a maximum degree of development.

The diurnal rotation is a motion whose direction is at right angles with the globe's axis, and oblique with reference to the ecliptic. If it causes a daily tidal alteration of level as between the land and sea surfaces, as it manifestly does, then it necessarily follows, all other things being the same, that from any alteration in the

direction of the earth's daily rotation, if it occurs, there must ensue a further change in the relative levels of the land and sea surfaces, beyond that which is occasioned by the daily revolution of the globe upon its axis.

Hence the questions that follow are of considerable geological importance: "While the earth ever continues to revolve upon the same imaginary line or axis, does the direction of its daily rotary motion undergo permanent alteration? and if it does, what is the nature and extent of that alteration?"

It is demonstrated by practical and theoretical astronomy, that the direction of the earth's diurnal rotation *does* become gradually and slowly altered; but it would seem to be only from an alteration involving an increase or diminution in the degree of angularity between the plane of the earth's equator and the plane of the ecliptic, that the geological effects alluded to would ensue. It is therefore proposed to analyse the explanations given to us by astronomers respecting that "obliquity of the ecliptic."

II. *The earth's precessional motion as it is usually described.*

The explanations of the part of the earth's motion which results in the "precession of the equinoxes," may be thus stated:—

The motion of the earth is compound: besides other motions, it has its daily rotary motion on its axis; its motion in orbit; and another motion of such a nature that each of its poles describes in space a circle — the circle

described by the north pole of the earth having over its centre a point in the heavens where the pole of the ecliptic is said to be situate; in fact, that point is called the pole of the ecliptic. The circles described by both poles of the earth's axis are of course parallel with each other, but it is only necessary to consider the circle described by the north pole.

The semi-diameter of this circle is measured or determined by an angle of 23° 28′, formed at the earth's centre by the junction of two straight lines, one being the earth's axis, and the other may be described as having the point called the pole of the ecliptic at one end of it, and as passing through the earth's centre.

Hence, each semi-axis of the earth describes a cone whose apex is in the earth's centre, and whose sides there converge and form an angle of twice 23° 28′. Therefore, the straight line from the pole of the ecliptic through the earth's centre forms the axis of both cones.

Of course, the plane of the earth's equator is always at right angles with the earth's axis, and it of necessity participates in that motion of the earth which, in fact, gives to the earth's axis the conical motion under consideration.

The time occupied by each pole of the earth in describing the circle is nearly twenty-six thousand years.

For present purposes the plane of the ecliptic may be supposed to hold an invariable situation in space throughout that period of nearly 26,000 years; its position being determined with reference to the fixed stars.

This precessional motion of the earth is thus described

by the Rev. Thomas Galloway, F.R.S., in the *Enc. Brit.*, vol. xviii., pp. 452 and 458:—

"By reason of the spheroidal form of the earth, and the intensity of the force of attraction varying with the distance, the action of a distant body which is not situated either in the plane of the equator or in the prolongation of the axis of rotation, produces an unequal effect on the opposite sides of every plane passing through the earth's centre, (excepting the meridian in which the body is situated,) and tends to generate a rotatory motion about that diameter of the equator which is perpendicular to the line which joins the centre of the earth with the centre of the attracting body. Hence, the sun exerts a force which at every instance has a tendency to bring the plane of the earth's equator towards the plane of the ecliptic; and if the earth had no motion of rotation about its axis, the two planes would at length be brought to coincide. In consequence, however, of the rotatory motion, the inclination of the two planes undergoes no permanent alteration; but a motion is given to the earth's axis, such that the pole of the equator constantly revolves about the pole of the ecliptic in the direction opposite to that of the diurnal rotation, and the intersection of the equator and ecliptic following the motion of the pole, is carried backwards along the ecliptic."

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"As the inclination of the equator to the ecliptic undergoes no permanent alteration in consequence of the action of the sun and moon, and as the precessional motion of the equinoxes is proportional to the time, it follows

that . . . the pole of the equator must describe a circle about the pole of the ecliptic, the plane of which is parallel to the ecliptic, and of which the radius is equal to the sine of the obliquity, or = sin (23° 28′). The mean velocity corresponding to the regression of the equinoctial points is 50″.4 in a year, and consequently the period of a revolution is about 25,900 years."

The same phenomenon is thus described by Sir John Herschel in his elementary *Treatise on Astronomy* :—

"It is found, then, that in virtue of the uniform part of the motion of the pole, it describes a circle in the heavens around the pole of the ecliptic as a centre keeping constantly at the same distance of 23° 28′ from it in a direction from east to west, and with such a velocity that the annual angle described by it in this, its imaginary orbit, is 50″. 10, so that the whole circle would be described by it in the . . . period of 25,868 years. It is easy to perceive how such a motion of the pole will give rise to a retrograde motion of the equinoxes."

In order that the present analysis may be seen to be in accordance with recognized astronomical explanations of that part of the earth's motion which results in "precession," the inquiry is further prefaced with the following definitions :—

The earth's motion in its orbit is so performed that the plane of the ecliptic passes through the earth's centre.

The earth's axis is not at right angles with the plane of the ecliptic. Hence, of course, the plane of the earth's equator is not parallel with that plane. The two planes intersect each other in a line passing through the

earth's centre, and so that they form an angle with each other along that line. The line of intersection is the "line of the equinoxes," or the "line of the nodes." The "nodes" are points where the extended plane of the earth's equator intersects the plane of the ecliptic—the equatorial plane being regarded, for convenience, as extending to the starry heavens, where its extremest limits form an imaginary circle called the equinoctial. The angular separation of the two planes is called the "obliquity of the ecliptic."

Those points of intersection or "nodes" are found to alter their situations in the starry heavens; they recede along that great fixed circle of the ecliptic which ever holds its place among the fixed stars. That alteration in the situation of the nodes or equinoctial points is occasioned by the precessional motion in question.

III. *The recognized explanations of precessional motion considered with reference to observed astronomical phenomena.*

For the purpose of ascertaining whether the angular divergence of the equinoctial from the ecliptic does or does not ever remain unaltered, let the recognized explanations of precessional motion be considered with reference to certain actual astronomical phenomena.

In the first place, then, precession causes or rather consists of an increase in the longitude of the stars.

This fact is consistent with either supposition—that is to say, so far as concerns that alteration in the apparent situations of the stars of which increase of longitude

consists, it might take place whether the angularity of the equinoctial plane, relatively with the ecliptic, does or does not become altered in degree.

But the means whereby the increase in the longitude of the stars and the recession of the equinoctial points is ascertained, seem to prove that that phenomenon *is* caused by an alteration in the angularity of the position of the equinoctial with reference to the ecliptical plane.

It is said by astronomers that their observations upon the pole of the heavens, or that vanishing point in space to which the north pole of the earth points, confirm the hypothesis that the earth has a gyratory motion which occasions "precession" in the manner they describe. They find, in fact, that the position of the pole of the earth (and hence the pole of the heavens) is ever undergoing a slow alteration with reference to the circum-polar stars. This is shown in the following extract from Sir John Herschel's *Treatise on Astronomy*, which also includes the quotation previously made therefrom :—

"The place of this point" (the pole of the equinoctial or the vanishing point of the earth's axis) "among the stars is easily determined at any epoch, by the most direct of all astronomical observations,—those with the mural circle. By this instrument we are enabled to ascertain at every moment the exact distance of the polar point from any three or more stars, and therefore to lay it down by triangulating from those stars, with unerring precision, on a chart or globe, without the least reference to the position of the ecliptic or to any other circle not naturally connected with it. Now, when this is done with proper

diligence and exactness, it results that, although for short intervals of time, such as a few days, the place of the pole may be regarded as not sensibly variable, yet in reality it is in a state of constant although extremely slow motion; and what is still more remarkable, this motion is not uniform, but compounded of one principal, uniform or nearly uniform part, and other smaller and subordinate periodical fluctuations, the former giving rise to the phenomenon of precession, the latter to another distinct phenomenon called nutation."

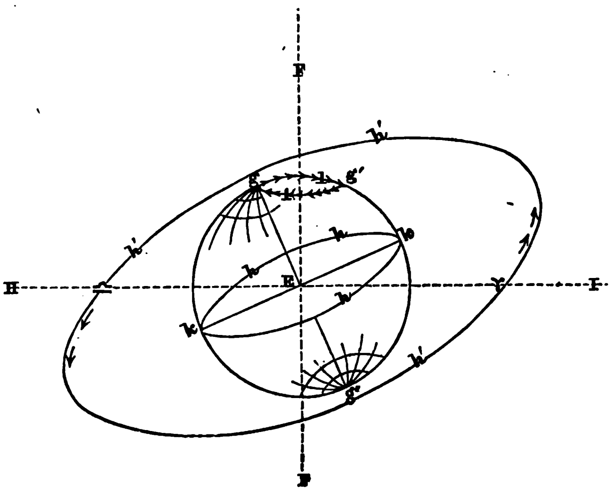
* * * * *

"It is found that, in virtue of the uniform part of the motion of the pole, it describes a circle in the heavens around the pole of the ecliptic as a centre, keeping constantly at the same distance of 23° 28′ from it in the direction from east to west, and with such a velocity that the annual angle described by it in this, its imaginary orbit, is 50″.10, so that the whole circle would be described by it in . . . 25,868 years."

It is of course easy enough to perceive that if the plane of the circle thus said to be described by the north pole of the earth round the pole of the ecliptic continues parallel with the plane of the ecliptic, no alteration in the angular relationship of the plane of the earth's equator to the plane of the ecliptic would ensue. The following diagram shows that such would necessarily be the case—for if the north pole of the earth g, in describing the circle $glg'l$, ever remained at the same distance from the plane of the ecliptic (in which is the line HI), the earth's axis must continue to form at the earth's centre (E), an angle of 23° 28′

with EF (being the imaginary line projected from the earth's centre towards the pole of the ecliptic in the direction of F); and hence the plane of the earth's equator *h h h* (whose diameter is the line *k k*), must of necessity ever retain the same angular relationship with the ecliptical plane, while the position of the line of the equinoxes (or the line of the junction of the two planes) is ever undergoing a slow alteration.

Regarding *h′ h′ h′* as an extension of the plane of the earth's equator to the starry heavens, the parts of it which intersect the plane of the ecliptic at the "nodes," would appear to recede among the stars in a direction contrary to that of the diurnal rotation, but the angles of 23° 28′, formed by the intersection of the two planes at the line of the equinoxes (namely, the angle *k*EI above the ecliptic and the angle HE*k* below it) would not vary.



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But let that motion of the poles of the earth be analyzed, it being, however, only the motion of the north pole that need be regarded, as the circumstances are, of course, the same in the case of both poles.

The plane of the circle the north pole is supposed to describe in space is said to be parallel with the ecliptical plane—that is, the north point of the earth's axis always remains at the same distance from the plane of the ecliptic. Although it is always being removed either further from or nearer to the centre of the earth's orbit, as the case may be, according to the part of the circle it happens to be describing, its distance from the ecliptical plane ever remains unaltered. And its motion is measured and determined with reference to the fixed circum-polar stars.

Let the statement be repeated. According to the explanations which have been quoted, and that may be regarded as authoritative, a circle is so described by the north pole in virtue of the alleged conical motion of the earth's axis under consideration, that in describing it, the pole is always being brought either nearer to or further from the sun's centre, but not nearer to or further from the ecliptical plane. And the motion is not a mere theoretical motion, but is actual, and is ascertained by observations made upon the circum-polar and other fixed stars, and it results in an alteration of the position held by the north pole of the earth, and by the vanishing point in the heavens (or that which is called the pole of the heavens) with reference to those stars.

Now astronomers say that the distance of the fixed

stars from the earth is so vast that, taking the diameter of the earth, or even the diameter of the entire orbit of the earth, as the base of a triangle converging at any of the fixed stars, or taking any two stars, however far distant from each other, for the two angles of a triangle, with the earth's centre for the third angle, they fail to obtain by angular measurements as referred to the fixed stars, any indication of the motion of the earth in its orbit, or if, having that diameter for a base, they do succeed in obtaining an angular measurement, its quantity is so minute as to be hardly capable of detection.

This fact is thus stated by Sir John Herschel * :—

" When we speak of the comparative remoteness of certain regions of the starry heavens beyond others and of our own situation in them, the question immediately arises, What is the distance of the nearest fixed star? . . . We have attained by delicate observations and refined combinations of theoretical reasoning to a correct estimate, first of the dimensions of the earth; then, taking that as a base, to a knowledge of those of its orbit about the sun; and, again, by taking our stand, as it were, on the opposite borders of the circumference of this orbit, we have extended our measurements to the extreme verge of our own system, and by the aid of what we know of the excursions of comets, have felt our way, as it were, a step or two beyond the orbit of the remotest known planet. But between that remotest orb and the nearest star there is a gulf fixed, to whose extent no observations yet made

* *Treatise on Astronomy*, p. 376.

have enabled us to assign any distinct approximation, or to name any distance however immense, which it may not, for anything we can tell, surpass.*

"The diameter of the earth has served us as the base of a triangle in the trigonometrical survey of our system by which to calculate the distance of the sun: but the extreme minuteness of the sun's parallax renders the calculation from this 'ill-conditioned triangle' so delicate, that nothing but the fortunate combination of favourable circumstances afforded by the transits of Venus could render its results even tolerably worthy of reliance. But the earth's diameter is too small a base for direct triangulation to the verge even of our own system, and we are therefore obliged to substitute the annual parallax for the diurnal, or which comes to the same thing, to ground our calculation on the relative velocities of the earth and planets in their orbits, when we would push our triangulation to that extent. It might be naturally enough expected that after this enlargement of our base to the vast diameter of the earth's orbit, the next step in our survey would be made at a great advantage,—that our change of station, from side to side of it, would produce a measurable and perceptible amount of annual parallax in the stars, and that by its means we should come to a knowledge of their distance. But after exhausting every refinement of observation, astronomers have been unable to come to any positive and coincident conclusion upon this head; and

* "This gulf no longer exists. Henderson, Bessel, and Struve, since the first publication of this volume, have filled it up or bridged it over. (1851.)"

it seems therefore demonstrated that the amount of such parallax, even for the nearest fixed star, which has hitherto been examined with the requisite attention, remains still mixed up with and concealed among the errors incidental to all astronomical determinations. Now such is the nicety to which these have been carried, that did the quantity in question amount to a single second (*i.e.*, did the radius of the earth's orbit subtend at the nearest fixed star that minute angle) it could not possibly have escaped detection and universal recognition."

The following quotation to the same effect is taken from the article upon astronomy appearing in the *Encyclopædia Britannica*, 8th edition, vol. iv. p. 81, and which was written by the Rev. Robert Main of the Greenwich Observatory :—

"The fixed stars being the points of departure from which all the celestial motions are estimated, one of the first objects in astronomy is to determine the amount and law of all the minute variations of position, real or apparent, to which they are subject. One of the most obvious consequences of the hypothesis of the annual motion of the earth is the existence of an annual parallax of the stars; but, on account of the enormous distances of those bodies, the effect of the earth's motion is so small that it cannot be easily measured: and there are even now very few cases in which, with the utmost refinements of methods and instruments, a measurable parallax has been detected. The longest line which nature has furnished us with the means of actually measuring, is the circumference of our own globe. . . But experience shows us that this scale, large as it is in our conceptions, is only

an insensible point in comparison of the distances of the fixed stars. Astronomy has furnished us with another base about 24,000 times longer than the former, or above 190 millions of miles. This is the diameter of the earth's orbit which is most conveniently used for expressing the distances of the planets and comets from the sun. Yet even this line is in general insensible when compared with the distances of the stars; for, on observing the same star from its two extremities at the end of six months, no variation whatever is perceptible in the star's position, after the proper corrections have been made for the small effects produced by different and known causes. The limits of the errors of modern observations cannot well be supposed to exceed 1″. It follows, therefore, that seen from the distance of the fixed stars, the diameter of the ecliptic, which exceeds 190 millions of miles, subtends an angle of less than 1″."

It is ascertained practically, then, that the diameter of the earth's orbit, which is a distance of at least 190 million of miles, is almost inappreciable, or literally as nothing in comparison with the distance of the earth from the fixed stars. In other words, *the earth's motion in orbit (a motion let it be remembered, which is in or is parallel with the ecliptical plane), cannot be detected with reference to the fixed stars*, even with the means which that vast line of 190 millions of miles presents for the purpose of actually ascertaining the fact.

The inference from this circumstance, as applied to the alleged revolution of the earth's north pole round the pole of the ecliptic, is obvious.

It is found that the north pole of the earth *does* change its place as referred to the circum-polar stars; it is actually, and in fact observed to alter its position in space in regard to them, while it ever retains (as it is said) the same angular distance of 23° 28′ from the pole of the ecliptic. The circle it describes round the pole of the ecliptic is said to be parallel with the plane of the ecliptic, and hence its motion is parallel therewith.

These alleged results seem to be utterly irreconcilable with each other. If the motion of the earth in its orbit, a motion that is in, or is parallel with the ecliptical plane, cannot be detected by means of angular measurements with reference to the fixed stars, when the diameter of the earth's orbit is used for a base, it is inconceivable that this motion of the earth's north pole, the yearly amount of which only gives a base that is infinitesimally minute as compared with the other, can be one that is parallel with the ecliptical plane.

The following diagram is intended as an illustration of what is here meant.

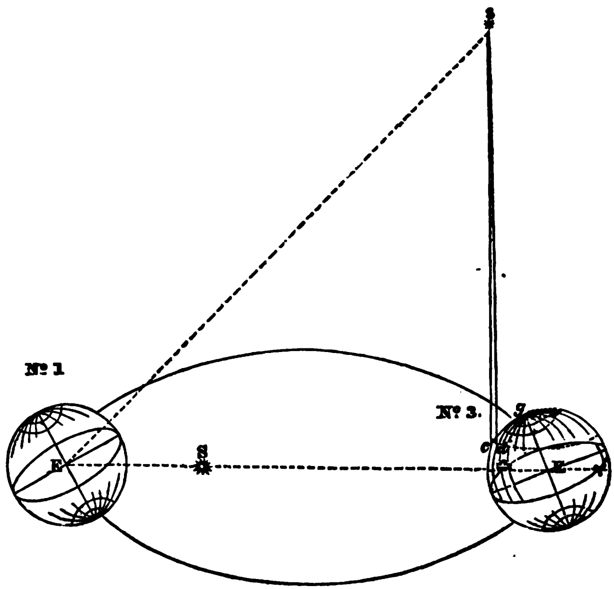
By its motion in orbit, the earth changes its position from No. 1 to No. 3 in the course of half-a-year, the linear distance between the two positions being equal to the longest diameter of the orbit (E to E), or at least 190 millions of miles.

With this line of 190 millions of miles for the base of the triangle E*s*E, no angle (or only an almost inappreciable angle) can be obtained by actual observation with reference to the fixed star *s*.

In consequence of precessional motion, the north

pole of the earth, *g*, is observed to change its position in a very small degree with reference to the star *s*. It describes a minute portion of a circle that is said to be parallel with EE. Hence the place of observation (as Greenwich) also describes a similar minute portion of a circle that is parallel with EE. So that while the distance is so great that the angle E*sd* *cannot*, the comparatively infinitesimal angle *c s d* *can* be detected!

It is obvious, that the circle described by *g* and the circle of which *c d* is a portion, *cannot* be parallel with the plane of the earth's orbit.



The circle said to be described by the north pole in consequence of precession, during about 26,000 of

the earth's journeys in orbit, is obviously of a far less measure than that of the globe's greatest circumference; but taking that extreme measure would give the circle a diameter of 8,000 miles. Hence, as it occupies 26,000 years for the circle to be described, the direct extent of the altered position of the north pole could not be more than $\frac{1}{26000}$ of 8,000 miles in half a year. Supposing, therefore, the motion to be parallel with the plane of the ecliptic, the result would be this: that whereas the altered position of the earth in space to the extent of 190,000,000 miles cannot be detected by reference to the fixed stars; but the altered position, during half a year, of the earth's north pole to the extent of less than $\frac{4}{13}$ of a mile ($\frac{1}{26000}$ of $8,000=\frac{8}{26}=\frac{4}{13}$) or certainly less than 541 yards, can be detected in reference to them—nay more, a day or two's precessional motion of less than two yards can, while the motion of 190 millions of miles cannot, be detected!

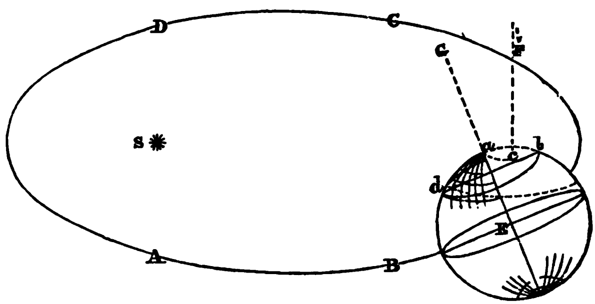
IV. *As to the actual effect of precessional motion.*

It being certain that the phenomenon of precession is brought about by an alteration in the position of the earth's axis, the question that forms the subject of inquiry on the present occasion relates solely to the character of that alteration. In fact, the question is, whether the plane of the earth's equator does or does not acquire an altered degree of angular divergence from the ecliptical plane.

Narrowed still further, the inquiry amounts to this,—What alteration in position does any spot on the earth's surface undergo in reference to the fixed stars, in conse-

quence of the precessional motion? Does the plane of the circle which that spot describes, by means of the daily rotation of the globe on its axis, always form the same angle with the plane of the earth's orbit? or does the motion of the globe through space become so altered that the circle thus described by every place upon its surface, undergoes a slow change in the angularity of its position relatively with the plane of the orbit? In short, is the diurnal rotation of the globe subject to a slight alteration in its direction, so as to bring every place upon the earth nearer to, or further from, the ecliptical plane?

The following diagram represents the condition of things on the supposition that the circle described by the north point of the earth's axis is really parallel with the plane of the ecliptic.



ABCD is the line described by the earth's centre E in the plane of the ecliptic; F is the pole of the ecliptic vertical over the plane of the ecliptic at E, the earth's centre. The small circle *a b c*, parallel with that plane represents the circle which the north pole of the earth's axis is said to describe. In describing that small circle

the north pole, or north point of the earth's axis, is here assumed ever to remain at the same distance from the ecliptical plane. The point *d* is the place of observation,—Greenwich, for instance, where the meridian and the circle or parallel of geographical latitude of that place intersect each other. The point *d* of course always remains at the same distance from the north pole of the earth, and therefore, putting the diurnal rotation of the globe out of consideration, the motion of the earth which causes the north pole to describe the circle *a b c*, must cause the point *d* to describe a circle which is parallel with the circle *abc*. And as *a b c* is parallel with the plane of the ecliptic, so also must be the circle described by the point *d*.

It, of course, must happen, under these circumstances, that the plane of the diurnal circle described by *d* in consequence of the *earth's daily rotation* on its axis, would always remain at the same angle of inclination to the plane of the ecliptic, and the circle described by *d* in consequence of precessional motion would be parallel with that plane.

But the distance of the fixed stars from the earth is so great, that neither the earth's motion in the ecliptic, nor any part of its motion that is parallel with the ecliptic, can be ascertained with reference to them.

It seems obvious that, under such circumstances, no change whatever could be observed to take place in the position of that point *d*, relatively, with the fixed stars generally, or with any circum-polar star particularly, and that the only possible alteration that would arise affecting the position of the place of observation with reference to the fixed stars, would be an apparent slight retardation or

acceleration, as the case might be, of the earth's daily rotary motion. It would take less or more time for the point *d* to reach the position it previously held relatively with the stars; that is to say, the time at which any particular stars would appear on the meridian at *d*, would alter to a small extent; but the equinoctial and the pole of the heavens would not alter their positions in relation to the ecliptic, and no alteration in the polar distances and declinations of the stars could become observable.

In fact, the effect would be exactly similar to that produced by the earth's motion in orbit, excepting that it would be proportionately less in degree. The time of the rising and setting of the stars would undergo a slight alteration, just as a considerable alteration in the time of their rising and setting occurs in consequence of the motion of the earth in its orbit.

Excluding from consideration for a moment the effects of precession, the part of the earth's motion which consists of its diurnal rotation on its axis may be said to cause every star apparently to describe either a circle whose plane exactly coincides with a circle or parallel of geographical latitude, or one whose plane is parallel with the planes of circles thus described by other stars. If, for instance, a plane could be made to pass through any part of the earth so that it should be parallel with the plane of the earth's equator, it would at every part of its intersection with the earth's surface be identical with a circle or parallel of geographical latitude; and if it were extended to any fixed star suitably situate in the heavens, then so far as the apparent effect of

the diurnal rotation is concerned, that plane would hold an unaltered position throughout any one revolution of the earth on its axis with reference to that star; in other words, the star would remain in the same plane. And as regards circum-polar and other stars not thus situate, the planes of the circles apparently described by them, in consequence of the earth's diurnal rotation, would be parallel with the planes of the circles described by those other stars.

That the planes of the circles apparently described by all the stars, by reason of the earth's diurnal rotation, are and must be parallel with each other, and with the planes of the earth's equator, and of all other parallels of geographical latitude, is obvious; for the earth's axis, or a line in prolongation of the earth's axis, forms the centres of those circles and planes, and passes through them at right angles with them.

And if it is found that the situation of a diurnal circle thus described by any star round the earth does, in fact, become altered, and the star comes to describe a circle whose plane is not coincident with the circle of geographical latitude with which it previously coincided, then, it being certain that the parts of the earth's motion which are parallel with the plane of the ecliptic cannot be detected by measurement as referred to the fixed stars, it seems manifest that the apparent change in the situation of the star arises, and can only arise, from a motion which is carrying the north pole of the earth either nearer to or further from the pole of the ecliptic, and the earth's equator either nearer to or further from the plane of the

ecliptic. And, similarly, any increase or diminution in the distance between the pole of the heavens and any circum-polar or other star which is not directly situate over a circle of geographical latitude, must arise from the same cause.

While, then, it is certain that the increase which is observed to take place in the longitude of the stars arises in consequence of the planes of the diurnal circles described by all places upon the globe becoming altered in position, with reference to the stars, it seems to be also demonstrable that the effect thus ensuing from the earth's precessional motion is of such a character that the inclination of those planes becomes at the same time changed relatively with the plane of the earth's orbit. In other words, a gradual alteration is ever in progress in the degree of the angularity which subsists between the earth's axis and the pole of the ecliptic, and between the earth's equator and the plane of the ecliptic. Hence, the plane of every circle of geographical latitude is always either gradually advancing towards or receding from the ecliptical plane. And this conclusion, which is to be arrived at by a very simple process of analytical reasoning in which no mathematical skill is required, is entirely based upon phenomena that are actually observed and made known to us by astronomers.

GENERAL DEDUCTIONS; PHYSICAL AND METAPHYSICAL.

I. *Introductory.*—It is a matter of frequent remark that in every department of creation with which we are familiar there are found the most plain and convincing evidences of beneficent design—that the adaptation of means to ends is manifest in all those varied operations and effects of nature with which we become acquainted in the course of our own experience, or which are made known to us through the researches and analyses of philosophers and men of science. To say nothing of the great and mysterious principle of life which exists in the almost infinitely various kinds of plants and animals abounding in air, earth, and water, it seems impossible to avoid seeing, in the chemical and mechanical provisions and arrangements that are combined and concentrated in living organisms, and in the means by which they are maintained and perpetuated, the most incontestible proof that such organisms have been designed by a Power that is almighty, omniscient, and all-beneficent, and which is ceaselessly exercised in behalf of the existences it has called into being. And in the phenomena revealed to us by astronomy and other branches of physical science, we are furnished with equally conclusive proof that the

inanimate part of creation has also been ordained, and is sustained by the same all-perfect Creator.

It seems difficult to understand why any one who employs himself in studying the operations and effects of physical nature should desire or endeavour to exclude from his attention the manifestations that present themselves on every side, of that wonderful originating Will to which actively or permissively all creation is attributable, or why certain facts and deductions that present themselves to his attention in the course of his investigations, should be rejected from his consideration merely because they are not of a physical character. For, surely, if creation is, indeed, referrible to One who has willed and designed its existence, the philosopher cannot be impeded but must be assisted by bearing in mind so much of the character and such of the attributes of the Creator as can be inferred from His works, and by obtaining if he can any, even the faintest, idea of His intentions regarding them, and of the objects and purposes for which they have been called into being.

Every one who makes any branch of physical science his particular study, is under the necessity of invoking aid from other branches. He could not prosecute his researches with any degree of success if he were to limit himself to the department which he has chosen for his specialty. Thus, the astronomer, the geologist, the chemist, and every other scientific investigator, is dependent upon facts and deductions which lie more or less out of his own particular domain. But why a different principle should be acted upon with regard to the facts of creation, which

are not of a physical character, seems difficult to understand. For the man of science, when engaged in tracing out the great truths of nature, to reject those facts from his consideration would in many instances amount to the rejection of important aids in his inquiries.

It may, perhaps, be regarded as absolutely true that nature has not been ordained in order only that physical forces might be set a-going, and that dead matter might acquire motion. It seems to be a necessary conception that all mere physical influences and existences have their being in respect of proximate or ultimate objects that are not physical. If this be so, then it cannot be deemed irrelevant for those who engage themselves in analysing the operations of physical nature and tracing their effects or manifestations from one proximate cause to another, to consider the utilities of those effects or manifestations apart from what is accomplished by mere mechanical or physical activity. And he, indeed, must be a soul-less individual, who only regards them as the results of inflexible and inevitable law; who feels no interest in the moral and spiritual purposes to which they are subservient; and whose investigations are not accompanied by any emotional admiration of that Being to whose Will all nature is subordinate.

It does not seem unreasonable to expect that there should be traceable among the records which the globe has stored up in itself, some evidences of the general laws that regulate the evolutions of nature, nor that the past history of our earth should, in however limited a degree, afford the means of deducing the order in which it has been

designed that the events composing that history should be developed. In the pages which follow an attempt will be made to trace a few general inferences in regard to those matters.

II. *There is no definable separation between the various departments of nature; but the physical and material elements are subordinate in importance to influences and existences that are not physical or material.*—It seems impossible to regard "creation" or "universal nature" otherwise than as a unique scheme or system which comprehends, undividedly, all things that are material and physical, and all that are moral and spiritual. Matter, for instance, is endowed with, or is capable of exercising, or is liable to be affected by invisible physical influences. Thus, one kind of influence—that of gravitation—is manifested in the motions of the heavenly bodies and in the motivity of ponderous objects that we can handle; and another kind of influence—that of chemistry—is exhibited in the dissolutions, affinities, combinations, and transformations that are ever taking place in the physical elements; yet no human being can say how or where those influences are separable from the substances they affect, nor, indeed, whether or not they are separable! Further, it is matter of positive experience that physical influences may be rendered active by an influence that is of a moral and not of a physical character—that is to say, by the mysterious power of reasoning will. A man wills that one or more physical influences shall assume a condition of activity when he projects a stone, lets fall a weight, or brings chemical

elements together. He devises mechanism, unites mechanical and chemical elements, and generates a physical power that he can use and perfectly control. These effects are produced in consequence of the exercise of that unseen, impalpable influence or energy—the will of the man; for unless he wills that the mechanical and chemical agencies should be called into activity, unless he devises the method of their operation, and compels by his will his own mechanical powers to acquire motion, the effects will not be produced.

We are surrounded with evidences of the mysterious union that subsists between influences that are and influences that are not physical. It is the thought or reason and the will of the architect, combined with the intelligently exercised volition of the skilled artisan, that produces a commodious and elegant edifice. By similar means a noble steam ship is devised and constructed and navigated. It is by the apparently uncontrolled volition of the military commander or political chief that great armies are moved about over the face of the earth. And it is by the intelligence and will of unseen agents that institutions of various kinds—political, religious, benevolent, and commercial—are organized and are made to achieve palpable results. In these and thousands of similar instances it is plain that mind and will, and physical force and matter—that is to say, some influences and existences that are physical and material, and some that are not physical or material—work undividedly together in accordance with and in obedience to laws which only an Infinite Wisdom and an Omnipotent Will could devise or ordain.

And yet it cannot but be regarded as a law or principle of nature, that material and physical influence or existence is merely secondary and subordinate in importance to influences and existences that are moral and spiritual. For, as already suggested, it seems impossible to conceive that the only object and purpose of creation is the mere activity of physical force,—the mere resultless combination and evolution of physical elements. The existence of a race to whose especial benefit and pleasure physical nature is subordinate—a race that is endowed with volition, with reason, with sympathy, and which in a limited degree can control the elements of nature, and is even so far independent of its Creator that it has the power to will to accept or refuse proffered benefits, and to pursue that which is right and true, or that which is evil and false,—seems in itself an abundant illustration of the relative importance of these two departments of the Creator's vast domain. It is evident that it is by his moral and spiritual attributes that man, to a very limited extent, can control and regulate the physical and material elements of nature.

It is not to be denied that the moral and spiritual as well as the physical and material laws, influences, and existences of creation all work together for good, and are all more or less co-adjustive and self-adjustive without needing perpetual interference at the hand of their Originator. But it appears impossible to conceive, without disregarding what nature reveals of the attributes of its Great Author, that the various functions of creation have been endowed with such an absolute fixedness and inevitability that their right working has ceased to be an object

of His solicitude, or that they should never require His governing and corrective superintendence. It seems as inconsistent with the revelations of the character of the Almighty which nature presents, to suppose that He has ceased to be interested in or to regard the continued well-being and progress of the universe that He has ordained, as it is impossible to believe that dead matter or mere physical existence possesses the god-like power of developing itself into reason and free-will endowed intelligences.

III. *A principle of gradual and ever-progressive development is deducible from the works of nature.*—This appears to be indicated in several ways.

(1) The structure of that small outer portion of our globe which is accessible to geological investigation, and is usually spoken of as the earth's "crust," seems to prove that our globe has passed through various phases of development, the earlier of which were preparatory to those that followed.

The fact that the nethermost portion of the earth's crust consists of but one general kind of material, shows that during an early period, the exterior condition of the entire globe was nearly uniform, and that the immediate effects of the agencies and influences that were then in activity at its surface, were very different in character from those that were afterwards accomplished. It seems probable that in that early era animal life did not exist upon the earth.

It is plainly indicated by the innumerable extinct volcanic vents that are to be seen in different parts of the

world, that the whole of the globe's surface has been in a condition of enormous volcanic activity. These evidences are corroborated by the fact, if it be a fact, that a material whose condition appears to be due to igneous agency, forms the entire nethermost part of the globe's crust. Although subterranean heat with volcanic force manifestly exists at the present day, yet it is evidently so insignificant in degree that it can only be regarded as the mere dying-out remnant of the generally prevailing heat of former ages. From these circumstances it is to be inferred that our globe has passed through a volcanic phase.

The vast sedimentary accumulations in a stratified form that now for the most part constitute the upper portion of the dry land, and their entombed animal remains, plainly demonstrate that the whole of the present dry land of the world has been submerged beneath the ocean. In fact, those deposits clearly indicate that the most recent operation to which the outer part of the earth's crust has been subjected is that of demolition and reconstruction by aqueous agency.

From the contour of the dry land it is certainly deducible that the disappearance of the water from former sea beds did not take place suddenly, for at all heights along such parts of the sides of the hills and mountains as have not been disturbed by the plough, there exist clear indications of the margins of ancient seas and lakes, and there cannot be a question that every river channel presents the plainest evidences of its waters having gradually diminished in volume; while many ancient sea cliffs, traceable at considerable distances from the sea-shores of our own times,

evidently remain exactly in the condition in which they were left by the receded waters, except that their former picturesqueness is enhanced by the vegetation which now more or less abundantly covers them.

That a most complete and perfect renovation of the globe's surface is ever in progress, is by no means the least interesting of the numerous circumstances which indicate a principle of gradual development in connection with the physical condition of the earth. The existence of the aqueous rocks over all the islands and continents of the world is of course demonstrative of the water having prevailed in former times over that which is now dry land. And while, by astronomical explanations, as well as by its own contour, the dry land is proved to have been formed by an operation that was most gradual though ceaseless in its progress, and that was tantamount to a recession of the water from previously submerged parts of the earth's surface, it is at the same time a well-known fact that at the present day, an effect equivalent to the recession of the sea is occurring upon some coasts, and that elsewhere the ocean is gradually encroaching upon and submerging the land.

To what cause or causes can be due those past and progressing "changes of level"? Surely it cannot be conceived otherwise of the great geological phenomena of which the aqueous rocks bear witness, than that they form part of the effects produced by those magnificent operations of nature out of which so great a multitude of the most beneficent results are being constantly evolved! They cannot be attributable to a fickle, indiscriminate upheaval of the

earth's surface, or to any physical dilation or expansion whatever of the earth's outer portion or "crust," but must result from the operation of the general laws or influences which are ever affecting the globe! In short, there is abundant reason for the belief that they are effects which are produced by the constant operation of the very laws and influences that give to our planet and its satellite their several motions, and that determine and regulate the condition of the waters of the ocean.

An endeavour has been made in other parts of this volume to describe the astronomical origin of geological phenomena so far as the sedimentary formations and the past and progressing alterations in the relative levels of the land and sea surfaces are concerned. Regarding them as properly assignable to that origin, how completely does it seem to harmonize with the great scheme of creation, as revealed to us in all the other departments of nature, that provision should have been thus made for the continuous renewal of the earth's surface, and for an ever-progressive alteration of climate and other concomitant circumstances, at a rate of progress so slow that no detriment whatever should thence be suffered by the myriad life which exists and is perpetuated upon our planet! Not a single individual of the numberless millions of living organisms of the globe is thereby inconvenienced or affected in the smallest degree, and, in fact, the change involved in that provision is so slow in its progress that it is almost inappreciable in the course of even the longest human life!

Every lover of nature admiringly appreciates the

beautifully varied character of our globe's surface, divided as it is into water and dry land, with its oceans and inland seas—its continents and innumerable islands; and we can all of us enthusiastically contemplate the different kinds of beautiful scenery to be met with in so many places, and which arises chiefly from the great irregularity of the earth's superficial contour. It is delightful to retrace, even in thought, the rambles we have had among the giant snow-clad mountains. The various aspects their numerous concomitants present under different degrees and kinds of light, and under various conditions of atmosphere, leave in the mind life-long pictures of a most enchanting kind. The glittering peaks that project towards the sky from their unscaleable precipices—their shining glaciers—their dark ravines—the cataracts of water that are ever being discharged into their vast and gloomy chasms—and their quiet valleys, often so picturesquely traversed by winding silvery streams—form but a few of the features which become impressed upon the memory after an Alpine excursion; and other descriptions of scenery afford a no less agreeable retrospect, whether it happens that our wanderings have been over elevated heath-lands, or along the margins of precipitous sea-shore cliffs, or in verdant river-intersected meadows, or through the fields of waving corn which chiefly characterize richly cultivated plains and more or less undulating districts.

The fact that this diversity of landscape is directly and principally due to the mode in which former vast sedimentary accumulations have become deposited at the bottom of ocean, lake, and river, seems calculated to

greatly enhance the delight and almost affection with which every one regards nature's enchanting scenery.

To the proof already alluded to of there being ever in progress an operation that is equivalent to a gradual lessening of the depth of the ocean in some parts of the world, and whereby the water comes to recede from many coasts and shores, some historical testimony might be added. It might be shown from actually extant records that at no vastly distant date the sea around our own English coasts stood at a higher level than it now does. It must, for instance, have been something more than the mere throwing up of a shingle bank, that the water has retreated as it has within the last decade of centuries from the Rye and Winchelsea cliffs. That result can hardly have been due to anything else than a permanent lessening of the depth of water near the coast. There lack not very many circumstances confirmatory of the ancient tradition, that the waters of the Black Sea once stood at a higher level than they now do. And the not unfrequent mention in the Bible of the drying up of sea and river seems to be suggestive that in earlier days the phenomenon of a gradual shallowing of the water was not unknown; for although the biblical allusions to the subject are in the form of prophecies, yet that fact does not weaken but, rather, strengthens the supposition, seeing the utterance of the prophecies must have been based upon a *knowledge* of the events that were to ensue.

(2) The principle of gradual development appears to be demonstrated by the palæontological records of the rocks, for the deeper that aqueous deposits are searched

the fewer and more simple in construction and in their functions are found to be the organic forms contained in them. And as with the mechanical or anatomical structure of those forms, so would it seem to be with regard to their sensitive, instinctive, and rational endowments. Incontrovertibly, the human race itself is the most recent animal organism that has appeared upon our own arena of creation.

(3) And lastly, it seems to be deducible from the written history of the human race, that the same principle is in operation in regard to what may be termed the moral and spiritual or intellectual part of man's being. For though there may have been periods in which the character of mankind has seemed to degenerate, or in which the world has appeared to suffer a kind of tidal recession in respect of its moral and spiritual or intellectual condition; yet, it is hardly to be denied, that taking into account the whole period in which the human history is comprised, our race has advanced from a lower to a higher degree of rational and spiritual existence.

This is not the place for discussing the question whether the so-called barbarian state of human communities is an original or a degenerated condition of mankind; but taking facts as they exist, the history of the whole world may, perhaps, be said to be epitomized in the history of a single nation.

If the course of geological events which is revealed in the existing condition of the aqueous rocks is properly attributable to astronomical causation, then no difficulty lies in the way of accounting for the geographical dis-

persion of animal life from a single locality. But without here entering upon that question, let the history of our own island be very cursorily glanced at as illustrating that principle of gradual development.

Whether it was, in consequence of its union with the remainder of Europe, or by other means, that our country became peopled, it may, perhaps, be taken for granted that the ancient inhabitants of Britain were originally grouped into families. Naturally, the governing influence in a family would be possessed by the most intelligent and athletic of its members. With an increase of population, a necessity would arise for neighbouring families to arrive at mutual understandings and agreements. These would be arranged by the family heads. Hence would ensue the establishment of verbal compacts and mutually binding laws. But feuds and disputes, which would also arise, would bring about conflicts, in which again the strongest and shrewdest of family heads would take the lead. The subjugation of the weakest communities to those that were strongest, and the merging of the weaker with the stronger would follow, and so tribes would become formed whose chiefs would be respectively possessed of considerable authority over the private members of the tribes.

In so early a stage of a nation's existence, rivers and forests would present effectual barriers against free intercommunication of the tribes, but as the population increased and a competition of intelligence ensued, mechanical skill would become more and more developed. The promptings to geographical discovery would be stimulated, and rivers of small dimensions would then no

longer bar the intercommunication of neighbouring tribes. Still, however, individual superiority of intelligence and strength would assert itself, and for its exercise discontents, feuds, and conflicts would afford ample opportunity and scope. A continual enlargement of tribal communities by growth, mergence, and coalition would take place. Intercommunication between some larger communities would, for a time, be retarded however, by the least easily overcome natural barriers, such as mountain ranges and river estuaries.

But a race of civilized interlopers appears upon the scene, to which the native population of necessity succumbs. This intellectually governed physical-force element,—so perfect of its kind,—serves the purpose of stimulating, moulding, and instructing the original stock; but wanting the moral characteristics which constitute the foundation of all human progress, it at length grievously collapses. The wealth and the mere intellectual concomitants of Pagan civilization being removed, the land seems to be threatened with a relapse into barbarism.

The raw material, however, passes through another lengthened phase of preparation. Nature sets about adjusting itself. The bounteous productiveness of our land is as the scent of prey to the voracious instincts of half-civilized hordes. The lust of gain, commerce, the excitable and enterprising spirit of discovery, and other influences, then served,—as they ever do serve,—to engender and maintain a healthy commotion among the moral elements of the world, and Britain, like every other then existing country, experienced its vicissitudes. Through the strife and violence that prevailed during a

long period, it must have seemed as if a recession in the tide of national history had set in; yet the effect was not permanent, for the influence of intelligence and moral superiority asserted itself, and at length the foundations of a great empire became manifested in its temporary government by an Octarchy or a Heptarchy. One after another the several kingdoms came to be merged into each other, and at last a single dominant rule was established through the continued operation of the same natural principle. Meanwhile neighbouring countries were similarly progressing, and an identity and a mutuality of interest being suggestive of unity in government, England, Scotland, and Wales, became at length transformed into a single dominion.

During the whole period in which numerous communities are gradually coalescing and merging together, the material wealth and prosperity of a country is also advancing. It cannot be denied, however, that material wealth and prosperity form only an ingredient, and that but a secondary or subordinate ingredient, in the progress of a nation. Nor is its advancement merely due to the intelligence of its people, coupled with the abundance of its natural resources; but it is the gradual development of the moral character of the inhabitants that seems to constitute the principal element in the high degree of civilization which a nation attains in the course of its centuries of history. Indeed, it would not be difficult to show, by illustration from history, that the rise or fall of a nation is a result that depends, primarily and mainly, upon the development or decadence of the moral attributes

of the individuals composing the nation, and in but a secondary degree from circumstances connected with its politics, its commerce, or its material wealth. If a community in prosperity; as well as during its struggles for a place among the nations, ceases not to regulate its conduct by the simple elementary principles of natural equity; if it continues to be governed with prudence, and to be animated by undaunted moral courage; and if the spiritual life of its people does not decay, it cannot but maintain the position it has acquired, for it exists in nature's own strength, and advances in its course with all the certainty of nature's own laws.

As in the case of a single country so would it seem to be with a continent. A nation that is strong in all the characteristics on which progress depends, cannot but exercise an influence upon the nations that surround it. The people along the frontiers become assimilated in language and in character. One neighbouring community after another is amalgamated with the principal governing community, until at length the continent becomes merged into a few great powers.

In our own days the same principle appears to continue its activity, and there seem to be looming rapidly into view some striking indications of further amalgamations. As a means, scientific, mechanical, and commercial enterprise is exercising a vast influence upon the peoples of the world. In a more developed form and on a much grander scale, the same ancient elements are faithfully performing their functions. The desire of gain is attracting its millions to hitherto unpeopled regions, and new nations are

growing into existence with an unprecedented rapidity; strifes between great continental communities are ending in the dominancy of the stronger communities; international law is extending its influence; mutual national interests are the occasion of numerous international compacts and treaties. While, however, the folly and destructiveness of strife, and the utility and advantages of peace are becoming more and more impressed upon legislators and people, legislators and governments are inconsistently maintaining the nations in a state of preparedness for war. Evidently the end is not yet; but the principle manifested in history ever holds its place. Albeit civilization is becoming world-wide, there exist many anomalous circumstances. Much crime is being committed. While the principle of association is, in various ways, accomplishing results that are of the most beneficent character, there are at work, on the other hand, extensive organizations for evil, which are more or less secret and subtle in their government and operations. The moral elements of the world appear to threaten commotion, and civil disturbance and collision among the nations are not improbable incidents. Plainly, the great stream of history, of which the events of our own time form a portion, is not uniform throughout its parts. At the present day it seems to be characterized by diverging currents, by eddies and back-waters; while in various places it appears to be travelling amidst rocks, or to be traversing shoals.

But, notwithstanding all this, there are some early-dawn tokens of an approaching day in which the whole

world will have been brought under the dominion of a single code of law and equity; when grander results than any ever yet exhibited in the history of mankind will have emanated from the operation of the principle of gradual development, by which the moral and spiritual being of the human race appears to be governed; and when all nations and people will have become willingly subjected to the rule of absolute righteousness and good will.

It cannot be questioned, that to this effect physical circumstances are contributive. Some conditions of climate,.for instance, are more favourable than others for the rational and spiritual, as well as for the physical development of the human race. This being so, does it not appear extremely probable, that the curious fact of civilization having ever journeyed, and of its still journeying from the east to the west, is due to the operation of some general physical law connected with the motions of our planet?

But though such effects result from the operation of what may be regarded as part of the natural laws of the universe, yet, seeing the proximate as well as the ultimate objects for which the physical operations of nature are designed are not of a physical character, it seems impossible, in reason, to believe, that the progress, and the manner of the working of the means whereby these effects are produced, are matters of indifference to the Great Being of Beings to whom all the moral, spiritual, and physical laws and existences of creation are subordinate.

IV. *Summary.*—It is now proposed to review, briefly, a few of the topics which have been discussed in the

foregoing pages, especially some that are more particularly connected with astronomy and geology.

In the phenomena of nature which it is the province of the philosopher to investigate, there seem to be traces of a system that is as vast, as magnificent, and as unique as it is possible for the human imagination to conceive. As the student proceeds in his researches, the range of his mental vision is being continually extended, and his spirit finds itself ever roaming amid new wonders in new regions. In analysing, as far as he can, the operations of nature that are in actual progress, and in tracing the effects manifested in nature to their immediate, proximate, and ulterior causes, he perceives that those operations and effects are evolved methodically and in accordance with law. His reason becomes more and more convinced that they have been called into existence by a wisdom and power that he can only regard as infinite. Throughout the myriads of the most various results that present themselves on every side, he finds to be traceable a unity and a perfectness of design that he can only attribute to the intelligence of One who is absolutely omniscient. He discovers in every region of nature to which his mind obtains access, the most abundant and convincing testimony that there is One Universal Spirit to whose active or permissive will the existence of all creation is referrible, and to whom, in a finite and dependent sense, man bears an image or likeness, both in respect of rational, moral, and spiritual being, and in regard to the ability to will the production of physical as well as moral and spiritual results. He finds that those of the infinitely varied

details of nature that he can comprehend, are regulated in accordance with general laws; and that while such of the past and present evolutions of nature as he is able to understand, appear to constitute together a unique entirety, there yet subsists through them all a principle of regular and ever-progressive development.

It can hardly happen that any one who is familiar with the motions of the earth and its satellite, as they are explained to us by astronomers, can fail to have a conviction that they have been designed and pre-ordained. However profound may be the mathematical estimate of the effects manifested in what is termed gravitation, there is no denying that those effects form but a constant and regularly acting part of the course of nature. Different spheres or aggregates of matter are observed to be continually moving round a central body, in an order that is constant, but which includes certain regulated deviations from absolute uniformity of progression and recurrence. Their motions are performed in accordance with some pre-ordained law or principle, and cannot be said to be the law or principle itself. Though they might be said to thus revolve in virtue of an influence with which they have been endowed, yet even in that case, the statement would only be tantamount to the assertion that the influence operates according to a pre-ordained law, — the influence is not the law itself. The constant recurrence in the same order of spring, summer, autumn, and winter, in consequence of the earth's motion in orbit and of the obliquity of the earth's axis, as referred to the ecliptic, is a result which it would be ridiculous to ascribe to chance,

or to any self-existent or self-developing and independent attribute of physical matter. That it is an effect which is referrible to the exercise of intelligence and volition that exist independently of the sun and the earth,—that it is an effect which has been designed and is produced in accordance with a pre-ordained law, —is as manifest as it is that any result which can be wrought by the simplest human contrivance is produced by human intelligence and volition.

Evidently, too, it has been designed for useful ends, that the moon should revolve round the earth in an orbit which is oblique in relation to the ecliptic. Had it been made to revolve in that plane, a large proportion of the inhabitants of the earth would have had to suffer the inconvenience of a monthly recurrence of a solar eclipse. The effects of the influence exercised by the same luminary upon the waters surrounding the globe afford another illustration of the beneficent results that are accomplished in consequence of its monthly journey round the earth being performed in an orbit that has so small a divergence from the ecliptical plane.

Some of the very numerous useful purposes fulfilled by the earth's diurnal rotation upon its axis are too self-evident to be overlooked by even the most indifferent observers. We can all appreciate the beneficial adaptation of that astronomical arrangement to the nature of the earth's inhabitants and productions. The repose and refreshment of night are necessary both to the animal and vegetable parts of creation; and the face of teeming and prolific mother earth would, indeed, be a gloomy and unproductive

waste, if the vivifying influence of the sun-light were not exercised upon it as it is, in consequence of that motion of the earth.

The manner in which the waters of the ocean are affected by the earth's diurnal rotation is especially interesting, showing as it does, some of the magnificent arrangements which almighty and all-beneficent Prescience has devised for the behoof of our planet and its occupants. Thus, the daily tidal alternations, which have already been commented upon in a former part of this volume, result from the attractive power of the sun and moon upon the water, and from the earth's diurnal rotation. It is plain that high-water being chiefly dependent upon the position of the moon in the heavens, is produced in consequence of the earth's rotation on its axis, bringing every sea-shore successively into positions whence that attractive power can be exercised in the greatest degree. If, too, the explanations suggested in some of the foregoing pages be correct, the production of ocean currents is another effect of our globe's diurnal rotation upon its axis, for by its means the nearly constant amount of attractive power which the sun and moon exercise upon the waters of the ocean is ever being brought into contest with an amount of attractive power as exercised by the earth, which is not the same in all parts of the world.

When it is borne in mind, how necessary it seems that the vast collection of water encircling the earth should be constantly maintained in a state of motion, in order that its life-supporting purity may be preserved, these various

astronomical influences appear to be adapted with marvellous perfection to that particular object, albeit it is only one of the very numerous purposes they are made to fulfil. Doubtless they do not form the only means whereby the proper chemical condition of the ocean is permanently sustained, for its own inherent saltness, the agitation produced by the winds, light and heat, and numerous other agencies, are ever at work for the accomplishment of that end; but that they thus affect the entire watery envelope of our planet on a grand cosmical scale, there cannot be a doubt, according to the explanations which astronomy affords.

Nor is it only in consequence of the diurnal rotation of the earth upon its axis that the solar and lunar attractive power produces these oceanic effects, for they are greatly varied and enhanced by the revolution of the moon round the earth, wherefrom there ensues a continual recurrence of the changes of oceanic condition from spring tide to neap tide, and from neap tide to spring tide.

A further effect of a similar character, but less observable in degree, is doubtless produced by the annual motion of the earth in its orbit, as well as by that slight periodic departure from absolutely uniform repetition which marks the moon's path round the earth and occasions the "nutation" of its nodes.

Let us again consider the geological phenomena revealed in the aqueous rocks, and which have been already adverted to as part of the effects resulting from the astronomical influences whereby the earth and its satellite, and the condition of the seas surrounding our planet, are

determined and regulated. It seems impossible to regard them otherwise than as some of the vast number of results that are produced by the operation of the one great principle or law,—the law manifested in what is called gravitation. And thus regarded, they present a striking illustration of the beneficent ends which appear to have been contemplated by an almighty and omniscient designing and pre-ordaining Power. In the daily alternations between high and low water, which occur in consequence of the solar and lunar attractive power, and of the earth's diurnal rotation on its axis, we see a continually recurring "change of level," as between the surface of the sea and that of the dry land; and while it is so limited in degree as to work no injury to the earth's inhabitants and productions, its effects upon the ocean are most beneficial. And from those other "changes of level" revealed by geology, which are vastly greater in degree than those consisting of the daily tidal alternations, but which are exactly similar to them in character, and which arise from the operation of the same great law or principle whence the tides emanate, we see results of a no less beneficent kind, but which only become fully developed in the course of very lengthened periods.

The absolutely undisturbed condition of the aqueous rocks most plainly refutes the supposition that the sea bed has been elevated above the surface of the water by the exercise of physical force from beneath—the structure of those rocks, and the superficial contour of every country, clearly indicate that the existence of dry land is due to an effect that was equivalent to a gradual subsidence of the

water beneath which the globe's surface had been submerged even to a depth of four or five miles in some situations. It seems to be plain, from the explanations which astronomy affords us, that it is in consequence of the earth's daily rotation upon its axis undergoing a most gradual change in its direction, that the bed of the ocean is made to rise gradually towards and above the surface of the water, and that as slow a submersion of continents and islands is simultaneously effected.

How marvellously perfect appears to be the relation with each other of all the parts of creation with which we are acquainted! What an infinite variety of detailed effects emanate through subordinate and intermediate agencies, from the ceaseless exercise of one great principle! Through its sustained operation, the face of the whole globe is ever being renewed in the constantly progressive, though most gradual formation of new deposits out of the materials set free by the demolition of previously existing rocks. The myriads of living organisms, whose home is in the great deep, have there provided for them a self-acting mode of sepulture (without which provision the seas would become uninhabitable), and their buried remains afterwards silently perform important chemical functions, and with the innumerable other chemical influences affecting the rock constituents, aid in the transmutation of the material of which the outer portion of our globe consists.

Almost every description of rock, from the nethermost granite to the most recent sedimentary deposit, is represented in our own country, where, in one situation or another,

each particular member of the entire series may be seen at or near the land surface. Most people have probably noticed how the colour and general character of the soil depends upon the nature of the immediately underlying material; and when hill-side stone quarries present opportunities for inspecting the geology of a locality in section, it may be seen how great is the effect of pluvial and other atmospheric influences in decomposing the upper portions of even the hardest material, and thus continually producing a new supply of fruitful soil to take the place of that which is gradually borne to lower localities.

It appears, then, that various important geological effects are indirectly attributable to the exercise of the very influences to which the motions of the earth and its satellite are due—to the influences, indeed, upon which the maintenance of the whole planetary system depends. Those influences present themselves to our attention as producing grand terrestrial results, which, during their gradual development, as well as in their full accomplishment, fulfil innumerable beneficent purposes. The maintenance of the ocean in a proper condition of equilibrium and the continual motion imparted to it, whereby, in conjunction with other causes, its life-supporting quality is preserved—the complete destruction and re-construction, in the course of ages, of the whole of the globe's surface—the preparation of the submerged parts of the globe for the new functions they have to perform upon attaining the condition of dry land—the mechanical and chemical combination, dissolution, and transformation of innumerable kinds of rock constituents occurring upon all parts of the

globe, the parts that are submerged as well as those that are above the sea,—are but a few of the operations and effects that are immediately, proximately, or ultimately referrible to those influences.

Perhaps it may be claimed for geology that it is better calculated than any other branch of science to engender in its followers an ever-augmenting faith in the Creator, who has ordained these evolutions of physical nature for the special behoof, as it would seem, of the countless hosts of more or less intelligent existences that teem upon our earth; for it is by geological analysis that the most irrefutable evidences are obtained of God's creative and sustaining Wisdom and Power and Beneficence; and it is by following up the leading and most conspicuous phenomena of geology to their producing causes, that we necessarily become familiarized with the great primary laws according to which the motions of the planetary system are maintained, and that we are able to trace in outline the past history of our globe, as well as to form some probable conjectures concerning the yet fuller condition of development which seems to have been designed for it and its inhabitants.

THE END.

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